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THE NOTEBOOKS
OF
LEONARDO DA VINCI

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OF
LEONARDO DA VINCI

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and Introduced
by

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OF
LEONARDO DA VINCI

Volume II

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The Nature of Water

'As from the said pool of blood proceed the veins which spread their branches through the human body, in just the same manner the ocean fills the body of the earth with an infinite number of veins of water.'

IF A drop of water falls into the sea when this is calm, it must of necessity be that the whole surface of the sea is raised imperceptibly, seeing that water cannot be compressed within itself like air. C.A. 20 r. a

Whether the surface of the air is bounded by the fire, as is the water by the air and the earth by the water, and whether the surface of the air takes waves and eddies as does the surface of the water, and whether in proportion as the body of the air is thinner than that of the water the revolutions of its eddies are greater in number: of the eddies of the water some have their centres filled with air, others with water. I do not know whether it is the same with the eddies of the surface of the fire. Of the eddies of the water all those which begin at the surface are filled with air, and those that have their origin within the water are filled with water; and these are more lasting because water within water has no weight as water has when it is above the air; therefore the eddies of the water round the air have weight and speedily perish.

C.A. 42 r. a

OF THE DELUGES OF THE GREATEST RIVERS

The deluges of rivers are created when the mouths of the valleys cannot afford egress to the waters that they receive from these valleys as rapidly as the valleys receive them.

The progress of the water is swifter when it falls at a greater angle.

OF WAVES

The wave is the recoil of the stroke, and it will be greater or less in proportion as the stroke itself is greater or less. A wave is never found alone, but is mingled with as many other waves as there are uneven places in the object where the said wave is produced. At one and the same time there will be moving over the greatest wave of a sea innumerable other waves proceeding in different directions. If you throw a stone into a sea with various shores, all the waves which strike against these shores are thrown back toward where the stone has struck, and on meeting others advancing they never interrupt each other's course. Waves of equal volume, velocity and power, when they encounter each other in opposing motion, recoil at right angles, the one from the stroke of the other. That wave will be of greater elevation which is created by the greater stroke, and the same is true of the converse. The wave produced in small tracts of water will go and return many times from the spot which has been struck. The wave goes and returns so many more times in proportion as the sea which produces it contains a less quantity of water, and so conversely. Only in the high seas do the waves advance without ever turning in recoil. In lesser tracts of water the same stroke gives birth to many motions of advance and recoil. The greatest wave is covered with innumerable other waves moving in different directions; and these have a greater or less depth as they are occasioned by a greater or less power. The greatest wave is covered with various waves, which move in as many different directions as there were different places from which they separated themselves. The same wave produced within a small tract of water has a greater number of other waves proceeding over itself, in proportion to the greater strength of its stroke and recoil from the opposite shores. Greater is the motion of the wave than that of the water of which it is composed. Many waves turned in different directions can be created between the surface and the bottom of the same body of water at the same time. The eddying movements can accompany the direct movements of each wave. All the impressions caused by things striking upon the water can penetrate one another without being destroyed. One wave never penetrates another; but they only recoil from the spot where they strike. C.A. 84 v. a

The movement of water within water proceeds like that of air within air. C.A. 108 v. a

Among irremediable and destructive terrors the inundations caused by rivers in flood should certainly be set before every other dreadful and terrifying movement, nor is it, as some have thought, surpassed by destruction by fire. I find it to be the contrary, for fire consumes that which feeds it and is itself consumed with its food. The movement of water which is created by the slopes of the valleys does not end and die until it has reached the lowest level of the valley; but fire is caused by what feeds it, and the movement of water by its wish to descend. The food of the fire is disunited, and the mischief caused by it is disunited and separated, and the fire dies when it lacks food. The slope of the valley is continuous and the mischief done by the destructive course of the river will be continuous until, attended by its valleys, it ends in the sea, the universal base and only resting place of the wandering waters of the rivers.

But in what terms am I to describe the abominable and awful evils against which no human resource avails? Which lay waste the high mountains with their swelling and exulting waves, cast down the strongest banks, tear up the deep-rooted trees, and with ravening waves laden with mud from crossing the ploughed fields carry with them the unendurable labours of the wretched weary tillers of the soil, leaving the valleys bare and mean by reason of the poverty which is left there.

Among irremediable and destructive terrors the inundations caused by impetuous rivers ought to be set before every other awful and terrifying source of injury. But in what tongue or with what words am I to express or describe the awful ruin, the inconceivable and pitiless havoc, wrought by the deluges of ravening rivers, against which no human resource can avail? C.A. 108 v. b

Prove and draw up the rule for the difference that there is between a blow given by water upon water, and by water falling upon something hard; and consider well also that as water falls upon other water, and it yields space to the blow, the percussion making the water open as it receives the blow, so the same result will occur in a vase when the water which is contained within it has been struck, for it will be the same as when falling water has struck against a hard substance which resists the blow. C.A. 153 v. d

OF RIVERS AND THEIR COURSES

Among straight rivers which occur in land of the same character, with the same abundance of water and with equal breadth, length, depth, and declivity of course, that will be the slower which is the more ancient.

This may be proved with straight rivers. That will be most winding which is the oldest, and that which winds will become slower as it acquires greater length.

Of waters which descend from equal altitudes to equal depths that will be the slower which moves by the longer way.

Of rivers which are at their commencement that will be the slower which is the more ancient, and this arises from the fact that the course is continually acquiring length by reason of the additional meanderings of the river; and the reason of this is explained in the twelfth section. C.A. 156 r. a

The cause which moves the humours in all kinds of living bodies contrary to the natural law of their gravity, is really that which moves the water pent up within them through the veins of the earth and distributes it through narrow passages; and as the blood that is low rises up high and streams through the severed veins of the forehead, or as from the lower part of the vine the water rises up to where its branch has been lopped, so out of the lowest depths of the sea the water rises to the summits of the mountains, and finding there the veins burst open it falls through them and returns to the sea below. Thus within and without it goes, ever changing, now rising with fortuitous movement and now descending in natural liberty.

So united together it goes ranging about in continual revolution.

Rushing now here now there, up and down, never resting at all in quiet either in its course or in its own nature, it has nothing of its own but seizes hold on everything, assuming as many different natures as the places are different through which it passes, acting just as the mirror does when it assumes within itself as many images as are the objects which pass before it. So it is in a state of continual change, sometimes of position and sometimes of colour, now enclosing in itself new scents and savours, now keeping new essences or qualities, showing itself now deadly now lifegiving, at one time dispersing itself through the air, at another suffering itself to be sucked up by the heat, and now arriving at the region of cold where the heat that was its guide is restricted by it.

And as when the hand under water squeezes a sponge so that the water that escapes from it creates a wave that passes through the other water, even so does the air that was mingled with the water when the cold[1] is squeezed out, flee away in fury and drive out the other air; this then is the course of the wind.

And as the hand which squeezes the sponge under water when it is well soaked, so that the water pent up within it is compelled to flee away and therefore is driven by force through the other water and penetrates it, and this second mass perceiving itself to be struck departs in a wave from its position, even so the new . . . makes . . .

C.A. 171 r. a

The sharp bends made in the embankments of rivers are destroyed in the great floods of the rivers because the maximum current drives the water in a straight course. But as this diminishes it resumes its winding course, during which it is being continually diverted from one bank to another, and as it thus grows less the embankment of the river becomes hollowed out.

But in this lesser depth the water does not move with uniform course, because the greater current leaps from one hollow to another of the opposite banks, and the sides of the water which border upon the embankment have the shortest course.

The rotundities in the islands of shingle formed by the angles of the embankment trace their origin to the chief eddies of the rivers, which extend with their revolutions among the concavities and convexities which are found alternately in the embankments of the rivers; and from these spring the tiny brooks, interposed between the sandbanks of the rivers and their embankments, and placed opposite to the hollows of the embankments of these rivers.

[1] MS., *quella del freddo.*

The entry of river into river produces the first meanderings of the river.

The meanderings of rivers in plains are occasioned by the rivers emptying themselves there.

If the winding river be altogether removed from its ancient bed and set in a straight channel, it is necessary that the rivers which pour themselves into it from two sides increase in length on the one side as much as they lose it on the other, the one that acquires length losing in swiftness, this swiftness being transferred to the one that grows shorter.

Cause the lesser rivers to enter into the greater rivers at acute angles; the advantage of this will be that the current of the greater river diverts the line of entry of the lesser river and does not suffer it to strike against the opposite bank.

Should however the lesser river be in flood at the time when the waters of the greater river are low the percussion of the lesser river will break the opposite bank of this greater river.

The largest of the curves of a river in a valley will always have its convex side facing the lower part of the breadth of the valley.

The meanderings of rivers are always greater in proportion as they are nearer to the spot where the lesser river enters the greater.

The waves of earth formed by the embankment of the rivers are continually changing their positions, the former being created anew where the latter have been washed away. C.A. 185 r. b

Prove whether a triangle thrown into still water makes its wave of perfect roundness in the end. C.A. 199 v. b

[*Sketch—figure of bubble resting on water*]

Why the bubbles which the water makes are half-spheres and those of the air are perfect spheres. Why the sides of the base of the half-sphere are spherical rectangles, and the contact which each has with the water does not cause it to form a projection above it but on account of its weight it has to bend and curve. C.A. 209 r. a

[*With drawing*]

The water that falls down from a height, will create a deep pool, which will continually increase, and its banks will often fall in. And the reason of this is that the water, which falls upon the other water, by the swiftness of its blow and by its weight causes it to give place, and passes down to its depths where it forms a hollow space, and through the stroke and the air, which as it falls is buried with it, it comes to rise up again and raise itself to a height by various channels, which expand like an opening bud, and the stroke of the water upon the bank proceeds in a circle and thus continuing it will gnaw and consume the surrounding shores. C.A. 215 v. d

The air by its nature does not flee away beneath the water; but the water which is supported round about it presses it out of itself and drives it forth.

Therefore one element does not flee away of itself out of the other element, but is driven out by it. C.A. 244 v. a

OF THE FLOW AND EBB OF THE SEA AND ITS VARIETY

The flow and ebb of the sea are due to the course of the rivers, which give the water back again to the sea with slower movement than the movement of their own current; and on this account necessity causes the water to rise to a height. And this river covers up its current again with the swift wave which in its recoil goes to meet the descending current of the river.

The wave of the river flows back against its current when the sea is at its ebb. After the return of the wave to the shore it there acquires new power from the approach of the river.

The flow and ebb of the sea are not caused by the moon or the sun, but by the greatest wave as it advances and falls back. But since the recoil is weaker than the advancing movement, as it is deprived of support, this hesitating movement would consume itself if it were not renewed by the help of the rivers; for these being immediately swollen by the approaching wave of the aforesaid tide, the wave produced by this swollen river becomes added to this ebb, and it strikes the opposite shores of the islands set over against it, and then leaps back, and so returns in its former course, and so continues, as has been said above.

This experience has taught us, for it is seen continually in every river, and especially as it strikes against the sides of its bays.

C.A. 281 r. a

The spiral or rotary movement of every liquid is so much the swifter in proportion as it is nearer to the centre of its revolution.

This that we set forth is a circumstance worthy of note; since movement in the circular wheel is so much slower as it is nearer to the centre of the revolving object. But this same circumstance is shown in the similarity of movement both as to speed and length in each complete revolution of the water, both in the circumference of its greater and of its lesser circle; but the curve of the lesser circle is as much less than that of the greater as the greater circle is more curved than the lesser. And so this water is of uniform movement in all the processes of its revolution, and if it were not so the concavity would instantly be filled up again. But because the lateral weight of this eddying mass[1] is twofold, such concavity has no permanent movement, and of such duplication of weight the first comes into being in the revolving movement of the water, the second is created in the sides of this concavity, and it supports itself there and finally falls headlong down upon the air which has filled up the aforesaid cavity with itself.

The movements of the air through the air are two, that is straight in the form of a column upwards, and with revolving movement.

But water makes this movement downwards, and makes it in the form of a pyramid, and makes it so much the more swiftly as the pyramid is more pointed. C.A. 296 v. b

OF THE UTILITY OF THE SCIENCE OF WATER

There were many of the chief towns of the districts which, through being placed upon their chief rivers, have been consumed and destroyed by these rivers, as was Babylon by the Tigris, by means of Cyrus . . . and so with an infinite number of regions; and the science of water gives exact information as to their defences. C.A. 305 r. a

Water falling perpendicularly into running water makes a curve as it enters and a curve as it rises. The summit of the part that rises in the air will not be in the centre of the base of this cavity, and this base will be oval. C.A. 343 v. a

[1] MS. *circulazion revertiginosa.*

OF RIVERS

The water falls in whatever is the line of the summit of its wave, and it moves more swiftly where this fall has less slant, and breaks more into foam where it meets with more resistance.

There, according to what has been stated, the waves break against the course of the river and never in the direction of its course, because water falling upon flowing water can never create a rebound upon something that flies away and does not await the stroke; but in the case of the opposite descent towards the course of the water, the water in the wave as it falls against the course of the river does not come upon water which flies away from its stroke, but upon water which is proceeding in the opposite direction to this fall; and consequently as the wave in its fall has four degrees of velocity and the water that comes to meet it is also of four degrees of velocity, the impetus of the wave acquires eight degrees of velocity, and therefore waves of rivers break against their current, and that of the sea breaks against the water that flies back from the shore against which it has struck, and not against the wind that drives it. C.A. 354 r. b

OF THE FLOW AND EBB OF THE WATERS

Every movement of water creates flow and ebb in every part of the river where the swiftness of its course checks it.

This is proved by the fact that where the course of the river is steeper it is swifter; and where it is more level it is slower. Therefore the level sea receives more water than it discharges; for which reason it is necessary for the water of the sea to rise to such a height that its weight overcomes the water that drives it; and then this water which has been driven descends from its height round about the base of the aforesaid hill, and that part which descends against the current mentioned before swells this current up in such a way that the upper part of its water is retarded, until the water that follows becoming more abundant subdues the ebb and creates a new flow. C.A. 354 r. e

The impetus made in the great current of the water preserves its line among the motionless waves as the solar ray may do in the course of the winds.

At one time the wave of the impetus is motionless amid the great current of the water, at another it is extremely swift in the motionless water, that is on the surface of the swamps.

Why does a blow upon the water create many waves? C.A. 354 v. a

The river which has always depth at the centre of its course will keep within its banks.

Where the channel is more confined, there the water runs more strongly than elsewhere, and as it issues from the straight it spreads itself furiously, and strikes and wears away the near banks which lie across its course, and often changes its course from one place to another.

C.A. 361 r. b

The movement of the wind resembles that of the water.

What is the difference between water which is drawn and water which is driven?

Water which is drawn is when the Ocean as it falls draws after it the water of the Mediterranean Sea.

Water driven is that caused by the rivers which, as they come into the sea, drive its water.

Amid all the causes of the destruction of human property, it seems to me that rivers on account of their excessive and violent inundations hold the foremost place. And if as against the fury of impetuous rivers any one should wish to uphold fire, such a one would seem to me to be lacking in judgment, for fire remains spent and dead when fuel fails it, but against the irreparable inundation caused by swollen and proud rivers no resource of human foresight can avail; for in a succession of raging and seething [waves], gnawing and tearing away the high banks, growing turbid with the earth from the ploughed fields, destroying the houses therein and uprooting the tall trees, it carries these as its prey down to the sea which is its lair, bearing along with it men, trees, animals, houses and lands, sweeping away every dike and every kind of barrier, bearing with it the light things, and devastating and destroying those of weight, creating big landslips out of small fissures, filling up with its floods the low valleys, and rushing headlong with insistent and inexorable mass of waters.

What a need there is of flight for whoso is near! O how many cities, how many lands, castles, villas and houses has it consumed!

How many of the labours of wretched husbandmen have been rendered idle and profitless! How many families has it brought to naught, and overwhelmed! What shall I say of the herds of cattle which have been drowned and lost!

And often issuing forth from its ancient rocky beds it washes over the tilled [lands] ... C.A. 361 v. a

Where the channel of the river is more sloping the water has a swifter current; and where the water is swifter it wears the bed of its river more away and deepens it more and causes the same quantity of water to occupy less space.

The shorter the course of the rivers the greater will be their speed. And so also conversely it will be slower in proportion as their course has greater length.

Where the superabundance of the water is not received within the depth of its channel, necessity causes it to fall precipitately outside its banks.

No part of an element possesses weight within its element unless it is either moved within it with impetus, or falls down within it, being drawn by it from within another element. C.A. 365 r. a

The course of a smaller flood of water conforms to that of the larger of the great floods, and changes course and keeps company with it and ceases to delve under the banks.

The proof of this is seen in the Po. For when it is low its water runs many times in cross-currents, and called by the low places and directing its way towards these it takes its course and strikes the bank in its foundations, and hollows these out causing wide destruction. But when it flows in full stream the lesser quantity which formerly with its cross-current had beaten upon the banks and hollowed them, abandons its course, being dragged in company with the greater volume of water and advancing along the line of its base it forbears to damage its banks.

A 23 v.

The water which falls by the line nearest to the vertical is that which descends most rapidly and gives itself with greatest blow and greatest weight to the spot on which it strikes.

Every stream of water when near to its fall will have the curve of the descent commencing on the surface before it commences in the depth.
A 24 r.

Water is by its weight the second element that encompasses the earth, and that part of it which is outside its sphere will seek with rapidity to return there. And the farther it is raised above the position of its element the greater the speed with which it will descend to it. Its qualities are dampness and cold. It is its nature to search always for the low-lying places when without restraint. Readily it rises up in steam and mist, and changed into cloud falls back again in rain as the minute parts of the cloud attach themselves together and form drops. And at different altitudes it assumes different forms, namely water or snow or hail. Constantly it is buffeted by the movement of the air, and it attaches itself to that body on which the cold has most effect, and it takes with ease odours and flavours. A 26 r.

It is not possible that dead water should be the cause of movement either of itself or of anything else. A 43 r.

THE BEGINNING OF THE TREATISE ON WATER

Man has been called by the ancients a lesser world, and indeed the term is rightly applied, seeing that if man is compounded of earth, water, air and fire, this body of the earth is the same; and as man has within himself bones as a stay and framework for the flesh, so the world has the rocks which are the supports of the earth; as man has within him a pool of blood wherein the lungs as he breathes expand and contract, so the body of the earth has its ocean, which also rises and falls every six hours with the breathing of the world; as from the said pool of blood proceed the veins which spread their branches through the human body, in just the same manner the ocean fills the body of the earth with an infinite number of veins of water. In this body of the earth there is lacking, however, the sinews, and these are absent because sinews are created for the purpose of movement, and as the world is perpetually stable within itself no movement ever takes place there, and in the absence of any movement the sinews are not necessary; but in all other things man and the world show a great resemblance.

OF THE SPRINGS OF WATER ON THE TOPS OF MOUNTAINS

Clearly it would seem that the whole surface of the ocean when not affected by tempest is equally distant from the centre of the earth, and that the tops of the mountains are as much farther removed from this centre as they rise above the surface of the sea. Unless therefore the body of the earth resembled that of man it would not be possible that the water of the sea being so much lower than the mountains should have power in its nature to rise to the summit of the mountains. We must needs therefore believe that the same cause that keeps the blood at the top of a man's head keeps water at the summit of mountains.

OF THE HEAT THAT IS IN THE WORLD

Where there is life there is heat, and where there is vital heat there is movement of vapour. This is proved because one sees that the heat of the element of fire always draws to itself the damp vapours, the thick mists and dense clouds, which are given off by the seas and other lakes and rivers and marshy valleys. And drawing these little by little up to the cold region, there the first part halts, because the warm and moist cannot exist with cold and dryness; and this first part having halted receives the other parts, and so all the parts joining together one to another form thick and dark clouds.

And these are often swept away and carried by the winds from one region to another, until at last their density gives them such weight that they fall in thick rain; but, if the heat of the sun is added to the power of the element of fire, the clouds are drawn up higher and come to more intense cold, and there become frozen and so produce hailstorms.

So the same heat which holds up so great a weight of water as is seen to fall in rain from the clouds sucks it up from below from the roots of the mountains and draws it up and confines it among the mountain summits, and there the water finds crevices, and so continuing it issues forth and creates rivers. A 54 V.

If heat is the cause of the movement of moisture cold stops it. This has been already shown by the example of the cold region which stops the clouds drawn by the hot element. As for the proof that the heat draws the moisture it is shown as follows:—heat a jug and set it in a vase with the mouth downwards, and place there some charcoal which has been lighted. You will see that the moisture as it retires before the heat will rise and fill the jug with water, and the air which was enclosed in this jug will escape through its opening.

Also if you take a wet cloth and hold it to the fire you will see the damp of the cloth leave its place, and that part of the moisture which has least substance will rise up, drawn by the proximity of the fire which from its nature rises towards the region of its element. In this way the sun draws up the moisture.

EXPLANATION OF THE PRESENCE OF WATER AT THE SUMMITS OF THE MOUNTAINS

I say that it is just like the blood which the natural heat keeps in the veins at the top of the man, and when the man has died this blood becomes cold and is brought back into the low parts, and as the sun warms the man's head the amount of blood there increases, and it grows to such an excess there with the humours as to overload the veins and frequently to cause pains in the head. It is the same with the springs which ramify through the body of the earth and, by the natural heat which is spread through all the body that contains them, the water stays in the springs and is raised to the high summits of the mountains. And the water that passes through a pent-up channel within the body of the mountain like a dead thing will not emerge from its first low state, because it is not warmed by the vital heat of the first spring. Moreover the warmth of the element of fire, and by day the heat of the sun, have power to stir up the dampness of the low places and draw this to a height in the same way as it draws the clouds and calls up their moisture from the expanses of the sea. A 56 r.

Of the opinion held by some that the water of some seas is higher than the highest summits of the mountains and that the water was driven up to these summits:

Water will not move from one spot to another unless to seek a lower level, and in the natural course of its current it will never be able to return to an elevation equal to that of the spot whence it first issued forth from the mountains and came into the light. That part of the sea which by an error of imagination you state to have been so high as to have flowed over the summits of the high mountains for so many centuries, would be consumed and poured out in the water that has issued from these same mountains. You can well imagine that during all the time that the Tigris and the Euphrates have flowed from the summits of the Armenian mountains,[1] one may suppose the whole of the water of the ocean to have passed a great many times through their mouths.

Or do you not believe that the Nile has discharged more water into the sea than is at present contained in all the watery element? Surely this is the case. If then this water had fallen away from the body of the earth, the whole mechanism would long since have been without water. So therefore, one may conclude that the water passes from the rivers to the sea, and from the sea to the rivers, ever making the self-same round, and that all the sea and the rivers have passed through the mouth of the Nile an infinite number of times. A 56 r and v.

OF THE FOAM OF WATER

Water which falls from a height into other water imprisons within itself a certain quantity of air, and this through the force of the blow becomes submerged with it. Then with swift movement it rises up again and arrives at the surface which it has quitted, clothed with a fine veil of moisture spherical in form, and proceeds by circles away from the spot where it first struck. Or the water which falls down upon other water runs away from the spot where it strikes, in various different branches, bifurcating and mingling and interlacing one with another; and some, being hollow, are dashed back upon the surface of the water; and so great is the force of the weight, and of the shock caused by this water, that through its extreme swiftness the air is unable to escape into its own element, but on the contrary is submerged in the manner that I have stated above.

[1] Text is not *de monti eruini*, as given in M. Ravaisson-Mollien's transcript, but *de mōti ermjnj* (*de monti ermini*), as given by Dr. Richter.

WHY RIVERS CHANGE THEIR POSITION AND OFTEN RAISE THEMSELVES AND MOUNT UPWARDS IN VARIOUS PLACES

The movement of water tends always to wear away its support; and the part which is the softest offers the least resistance, and as it vacates its place it leaves various hollows in which the water, whirling round in divers eddies, wears away and hollows out and increases these chasms, and striking against the newly-bared dikes leaps back and strikes upon the banks, consuming and eating away and destroying whatever stands in its path, changing its course in the midst of the havoc it has made, dragging with it in its course the lightest of the soil and then depositing it in the parts that are more tranquil. As it raises its bed the quantity and force of the water is lessened and its fury is transferred to the opposite side, and when it reaches the bank it eats it away and lays its foundations bare until with great destruction it has uncovered new ground. If it should find a plain it covers it, and carrying away and hollowing out it forms a new bed, and if it should come upon buried stones it uncovers them and lays them bare. But it often happens that these, because of their size, make resistance to the impetuous flood, and so after being driven against the rocks that are in the middle of its course it leaps back towards the opposite side, breaking and destroying the opposite bank. A 59 r.

WHY WATER DIGS OUT ROUND PITS WHEN IT FALLS WITH VIOLENCE

Water which falls in the manner stated does not enlarge its pit, for as the fact of it falling perpendicularly shows, there is but little force in the water that drives it from behind, and this is why it falls all broken and in fine spray almost in a perpendicular line. And the air which is amidst this broken water having an almost equal weight above it cannot escape so quickly as not to be submerged by the weight together with the blow. But, since air cannot be disunited from its element without violence, after yielding to the fury of the blow and the weight, it rises again quickly and returns to the surface in round bubbles near to the spot that was struck, and so as it does not move any distance from this spot it does not cause any damage to the banks of the pit. But when the rushing river, swollen by recent rains, scours its banks, it falls in fury into the lower waters, and no longer as formerly descending peacefully in a shower mingled with air upon the other water but united and strong, strikes and tears open the smitten depths right down to their rocky bed, uncovering and carrying away the buried stones, setting up for itself a new barrier in the shingle carried from the pit which it has made it throws itself upon it and falls back beaten, and divides at the blow into two different streams which separate and form half-circles, devouring and consuming every obstacle and enlarging their bed in the form of a circle.

To put it more exactly—when the rivers are in flood, the falls of the water are less abrupt, and therefore, as the mass of water strikes the lower levels, the water which follows the blow does not hasten with the violence of that which falls, and this being the case it offers resistance and thus offering resistance the water rises and the fall becomes shorter. In consequence it does not imprison so much air, because the lower parts of the water are hardly separated from the rest in its fall and, owing to this, very little air can enter, and therefore the blow and weight of the water meet with no resistance, and the blow proceeds without diminishment right down to the bottom, displacing the gravel that is there and surrounding and clothing the stones with itself and increasing the depth of the pools. A 59 r. and v.

OF THE WAY IN WHICH PITS ARE FORMED IN THE COURSES OF RIVERS

The reason is that in the beds of rivers there are always found stones of different sizes, and as the water, coming to the largest, sinks down behind them and smites the spot on which it falls, the blow dislodges the lesser stones from the spot on which it strikes, and the bed is made larger. As the fall increases it becomes more powerful and hollows out even more the pit which has been begun; and this occurs because the rivers constantly gnaw the mud of their bed and constantly uncover and lay bare rocks of different forms and sizes.

WHY THE SURFACE OF FLOWING RIVERS PRESENTS ALWAYS PROTUBERANCES AND HOLLOWS

The reason of this is that just as a pair of stockings which cover the legs reveal what is hidden beneath them, so the part of the water which lies on the surface reveals the nature of its base, inasmuch as that part of the water which bathes its base, finding there certain protrusions caused by the stones, strikes upon them and leaps up raising with it all the other water which flows above it. A 59 v.

WHY IF IN THE LEVEL BED OF A STREAM THERE IS A SOLITARY ROCK THE WATER BEYOND IT FORMS MANY PROTUBERANCES

The reason of this is that the water which strikes this rock afterwards descends and makes a kind of pit, in which in its course it searches for the hollow and then leaps back to a height and again falls down to the bottom and does the same, so continuing many times, like a ball that is thrown on the ground which before it finishes its course makes many bounds each smaller than the one before it.

WHAT CAUSES THE EDDIES OF WATER

All the movements of the wind resemble those of the water.

Universally all things desire to maintain themselves in their natural state. So moving water strives to maintain the course pursuant to the power which occasions it, and if it finds an obstacle in its path it completes the span of the course it has commenced, by a circular and revolving movement.

So when water pours out of a narrow channel and descends with fury into the slow-moving currents of mighty seas—since in the greater bulk there is greater power, and greater power offers resistance to the lesser—in this case, the water descending upon the sea beats down upon its slow-moving mass, and this cannot make a place for it with sufficient speed because it is held up by the rest of the water; and so the water that descends, not being willing to slacken its course, turns round after it has struck, and continues its first movement in circling eddies, and so fulfils its desire down in the depth; for in these same eddies it finds nothing more than its own movement, which is attended by a succession of circles one within the other; and by thus revolving in circles its course becomes longer and more continuous, because it meets with no obstacle except itself; and this motion eats away and consumes the banks, and they fall headlong in ruin. . . . A 60 r.

THE EDDIES AT THE BOTTOM OF WATER MOVE IN AN OPPOSITE DIRECTION TO THOSE ABOVE

The reason of this is that, if the circles which above are large become reduced to a point as they are submerged, and then continue their movement in the direction in which it began, the water will at the bottom make a movement contrary to that above when it separates itself from its centre.

Although the sounds which traverse the air proceed from their sources by circular movements, nevertheless the circles which are propelled by their different motive powers meet together without any hindrance and penetrate and pass across one another, keeping always their causes as their centres.

Since, in all cases of movement, water has great conformity with air, I will offer it as an example of the above-mentioned proposition. I say that, if at the same time you throw two small stones into a large lake of still water at a certain distance one from another, you will observe two distinct sets of circles form round the two points where they have struck; and as these sets of circles grow larger they come to meet together and the circles intersect one with another, always keeping as their centres the spots which were struck by the stones. The reason of this is that although some show of movement may be visible there, the water does not depart from its place because the openings made there by the stones are instantly closed; and the movement occasioned by the sudden opening and closing of the water makes a certain shaking which one would define as a quivering rather than a movement. That what I say may be more evident to you, just consider those pieces of straw which on account of their lightness float on the surface of the water and are not moved from their position by the wave that rolls beneath them as the circles widen. This disturbance of the water, therefore, being a quivering rather than a movement, the circles cannot break one another as they meet, for, as all the parts of water are of a like substance, it follows that these parts transmit the quivering from one to another without changing their place, for, as the water remains in its position, it can easily take this quivering from the parts near to it and pass it on to other parts near to it, its force meanwhile steadily decreasing until the end. A 61 r.

The winding courses of the water caused by the rebounds of the percussions which they make against the banks will cause the bed of the river below them to be more hollowed out than any other part; and in their percussions they will become of great depth; and the water that is whirled round near to these deep places will serve to undermine and destroy the banks against which it strikes.

One both clearly sees and recognises that the waters which strike the banks of the rivers act in the same way as balls which, when they are struck against walls, rebound from these at angles similar to those at which they strike, and proceed to strike against the opposite sides of the walls. So these waters after having first struck against the one bank, leap back towards the opposite one and strike upon it and hollow it out with vigour, because there is a greater confluence of water in this spot. The reason of this is that the water which leaps back from one bank to another hollows out that part of the bed of the river which finds itself beneath it; and the other water of the river which cannot be received in this low part remains repulsed and thrown back somewhat by the direct course of the river. And having no way of escape, it returns to its natural course, that is, that, as the bed of the river finds itself lower under the winding ways made by the above-mentioned percussions of the waters, this second water, which has lost its adventitious means of escape, resumes its natural course, falls into the lower parts of the river and strikes the banks at the same spot as that which witnessed the percussion of the aforesaid rebounds. As this bank is thus assailed by two entirely different sets of percussions a larger hollow is caused in it, for, while the first strike the bank above, the others descending more steeply devour and lay it bare at its base, and this is the cause of the aforesaid destruction and subsidence of the banks. A 63 v.

OF WATER

No part of the watery element will raise itself or make itself more distant from the common centre except by violence. No violence is lasting. c 15 r.

THE LEAP OF WATER IS HIGHER IN A BUCKET THAN IN A GREAT LAKE

This is because [confined] water when struck by a blow cannot make its impetus pass from circle to circle as it would in a great lake; and since the water when struck finds near to itself the edges of the bucket, which are harder and more resisting than the other water, it cannot expand itself, and consequently it comes about that the whole of its impetus is turned upwards; and therefore water struck by a stone throws its drops up higher when its waves are confined than when they have a wide space. c 22 r.

[*Of the motion of water*]

Water or anything falling upon water causes the water that receives the blow to spread itself out beneath the blow and to surround it, and having passed over the cause of this blow it continues above it in pyramidal shape and then falls back to the common level.

The reason of this is that when a drop of water falls from a roof upon other water, the part that receives the blow cannot find room or escape within the rest of the water with the speed with which it has been attacked, because it would be necessary for it to support too much weight in order to enter under so great a quantity of water. Having therefore to obey its own course as well as the action of that which drives it from its place, and finding that as the adjacent water does not receive the blow and is not ready for a similar flight it cannot penetrate it, it seeks instead the shortest way and flows through the substance that offers it less resistance, namely the air.

And as this first circle that surrounds the place which has been struck closes up with fury, because it was raised above the common surface of the water, it reduces the water that escapes upwards to the form of a pyramid.

And if you think that the water which falls was the same as that which leaps up, make a small stone drop into the water and you will see the water leap up in the same way and not the stone. C 22 v.

Every part of water within other water that is without movement lies equally at rest with that situated at the same level.

Here experience shows that if there were a lake of very great size which lay without movement of wind either entering or departing, and if you were to remove a very small part of the height of the bank which is below the surface of the water, all the water that is above the top of the bank that was cut away will pass through this cutting, but will not set in movement or draw with it out of the lake any part of the water that lay there before this water moved and went away.

In this instance nature is constrained by the workings of its law which lives infused within it, namely, that all the parts of that surface of the waters which are supported by the banks without any opening or exit are situated at an equal distance from the centre of the earth.

C 23 v.

HOW IT IS POSSIBLE FOR LARGE STONES TO BE ROLLED OVER BY WATER

Know that stones are rolled over by water because this water either surrounds or flows over them. If it surrounds them it meets again beyond them and intersects, hollowing out the soil or sand beyond the stone, and this after being thus laid bare begins to roll of itself. And if the water flows over the stone, then after it has done so it falls in the same line, and by the force of its impetus penetrates from the surface to the base of the other water, and gnaws and tugs and drags away the stone from the opposing obstacles with the result that this also begins to roll, and so continues from place to place until it traverses the whole river. And if a lesser stone should stand in its path the water uncovers it by the same process and does the same, and in this way stones are rolled over in the beds of flowing rivers. C 24 v.

A horse or man or any other creature that makes its way through stagnant water of medium depth will cause this water to rise and cover a quantity of the shore towards which this creature is directing its course.

This may be clearly demonstrated; for if you take a step in this water you will find that it makes a wave which directs its course and moves in the same direction as that in which the creature is travelling; nor does it pause until it has achieved its desire and covered a small part of the shore.

A second step creates another wave which has a similar result, and the same with the third and all the steps; each of itself creating a wave that travels as far as the shore, in such a way that this shore which formerly was uncovered finds itself covered by water over a great distance—then when you have emerged from this water you will see it returning to its former position in swift course. C 25 r.

Waves of rivers that flow against the courses of the winds will be of greater height than others.

The rivers that move against the courses of the winds will have a greater current below than above, as their surface on being driven by the winds becomes slower than it was at first.

The reason of this is that if the rivers, being of equal depth and breadth, are of uniform current at the bottom and on the surface, the resistance made by the wind to the current on the surface must necessarily cause it to turn back, and as it does not suffice these waves to raise themselves a little, falling at last they enter underneath the others and proceed to the bottom. Finding there the other current of the bottom it accompanies it, and as the bank is not capable of containing this increase it is necessary that at the bottom the current doubles itself; if it were not so one would see the water rising far above the banks of the rivers. C 25 v.

The stone placed in the level and smooth beds of flowing rivers becomes the cause of their inequality and deterioration.

When an object which is dropping down strikes upon another object harder than itself it suddenly makes a rebound which is so much greater as it has had a greater fall. When therefore a stone is situated beneath the surface of running rivers, the greater its size the greater is the percussion that takes place when water falls from its summit upon the beds of the rivers, and on account of this it comes to produce a deeper hollow in the place struck by this water.

After this first percussion many rebounds will follow, and these will become larger in size and less powerful as they are farther removed from the first.

The embankment which sends forth the trunk of the tree that it has nourished, to project into the waves of the rapid rivers, will become the cause of the destruction of the opposite bank.

The cause of this effect is that the water that flows in the rivers always goes leaping from bank to bank. If nothing projects in this bank many lines of water gather there and unite together and leap in a mass on the opposite bank, and twist themselves in with the other lines which they meet with on their way; and having reached the embankment they gnaw and destroy it. And there are yet new lines produced there which leap back and damage the other bank; and so from place to place they begin to form eddies of varying depths, and hence it comes about that straight rivers become winding and crooked.

c 26 r.

WHAT WATER IS

Of the four elements water is the second least heavy and the second in respect of mobility. It is never at rest until it unites with its maritime element, where, when not disturbed by the winds, it establishes itself and remains with its surface equidistant from the centre of the world. It is the increase and humour of all vital bodies. Without it nothing retains its first form. It unites and augments bodies by its increase.

Nothing lighter than itself can penetrate it without violence.

It readily raises itself by heat in thin vapour through the air. Cold causes it to freeze. Stagnation make it foul. That is, heat sets it in movement, cold causes it to freeze, immobility corrupts it.

It assumes every odour, colour and flavour, and of itself it has nothing. It percolates through all porous bodies. Against its fury no human defence avails, or if it should avail it is not for long. In its rapid course it often serves as a support to things heavier than itself. It can lift itself up by movement or bound as far as it sinks down. It submerges with itself in headlong course things lighter than itself. The mastery of its course is sometimes on the surface, sometimes in the centre, sometimes at the bottom. One portion rises over the transverse course of another, and but for this the surfaces of the running waters would be without undulations. Every small obstacle whether on its bank or in its bed will be the cause of the falling away of the bank or bed opposite to it. When the water is low it does more damage to the bank in its course than it does when it flows in full stream. Its parts do not weigh upon the parts placed beneath them. No river will ever keep its course in the same direction between its banks. Its upper parts do not impart weight to the lower.

[*An experiment*]

WATER AND AIR

I wish to show you in what manner water can be supported by air while being divided and separated from it. Certainly if you have reason in you, I believe that you will not deny that if there be a leather bag placed at the bottom of the water in a well, so as to touch all its sides, in such a way that the water cannot pass beneath, if this leather bag be filled with air it will not exert less force in rising to the surface of the water to find the other air than the water makes in its desire to touch the bottom of the well. And if this leather bag desires to rise up it will push up the water that is placed above it, and by raising this water it will take its weight from off the bottom of the well. For this reason therefore it is almost as though the well were bottomless.

Where and why the movement of the water ought to hollow out the sand of the surface of the beds of flowing rivers—but to speak first of the percussion on the surface:

The more rapid the current of the water along the slope of a smooth canal the more powerful will be its percussion against whatever opposes it.

For all the elements when removed from their natural position desire to return to it, especially fire, water and earth; and the shorter the line along which this return is made, the straighter its course, and the straighter its course the greater the percussion upon whatever opposes it.

The same effect is produced by the wind blowing through streets of uniform width. C 26 v.

THE ORDER OF THE FIRST BOOK ON WATER

Define first of all what is height and depth, also how the elements are situated one within the other. Then what is solid weight and liquid weight; but first of all what weight and lightness consist of in themselves. Then describe why water moves, and why its motion ceases; then why it becomes slower or more rapid, and in addition to this how it continually descends when in contact with air that is lower than itself; and how the water rises in the air through the heat of the sun and then falls back in rain. Further, why the water springs from the summits of the mountains, and whether any spring of water higher than the ocean can pour forth water higher than the surface of this ocean; and how all the water that returns to the ocean is higher than the sphere of the water: and how the water of the equinoctial seas is higher than the northern waters, and is higher beneath the body of the sun than in any other part of the circle of the equator; for when the experiment is made under the heat of a burning brand, the water boils as the effect of the brand, and the water around the centre of where it boils descends in a circular wave. And how the waters of the north are lower than the other seas, and more so as they become colder, until they are changed into ice. E 12 r.

[*Rivers*]

That river which stretches itself out most by long tortuous windings is the one which becomes filled up most rapidly with matter. This is proved by the twelfth, which says:—the water that loiters most discharges most rapidly the matter that it carries. Therefore the river which by meandering more makes itself longer by means of its twists and turns makes itself so much slower in proportion as it makes itself longer. E 66 v.

Of the difference that exists between the accidents of water and the accidents of air and fire:

Water is not capable in itself of being either condensed or rarefied, but it exists in as great quantity in front of the fish that penetrates it as behind it, and it opens itself up as much in front of that which penetrates it as it closes up behind this penetrating thing. And the impetus of the fish is of briefer duration than that of the bird in the air, although the muscles of the bird are very powerful in relation to their quantity; because the fish is all muscle and this is very necessary because it is in a heavier substance than the air. But although the water is not itself capable of being condensed it is of a nature to acquire gravity and levity. It acquires gravity at the destruction of the impetus which raises it in the air at the creation of the wave, and levity by the creation of the impetus that lightens the water and causes it to move contrary to the natural course of heavy things.

OF THE VALLEY INTERPOSED BETWEEN THE WAVES

The valley interposed between the waves is lower than the general surface of the water, as one sees when the water turns back in order to fill up the places that have been struck by the water-spouts.

E 71 V.

OF SURFACE EDDIES AND THOSE FORMED AT VARIOUS HEIGHTS OF THE WATER

Of those that take up the whole of this height and of the moving and the fixed. Of the long and the round. Of those that change their movement and those that divide, and those that become merged in those [eddies] to which they unite themselves, and those that are mingled with the falling and reflex water and make it spin around.

Which are the eddies that cause light things to whirl round on the surface and do not submerge them? Which are those that submerge them and cause them to spin round upon the bottom and then deposit them upon this bottom? Which are those that separate the things from the bottom and throw them back to the surface of the water? Which are the slanting eddies, which are the straight, which are the shallow?

F 2 r.

PLAN OF THE TREATISE ON WATER. SWIMMING

When you put together the science of the movements of water remember to put beneath each proposition its applications, so that such science may not be without its uses.

Of the usefulness of the courses that the swimmer ought to follow with regard to the surface revolutions of the waters and as to their eddies which submerge these swimmers. Then how he ought to direct himself when submerged in order to save himself, and so forth.

And at the end of each book notice the things that are most remarkable, as how to break through the thickness of the eddies in any direction. Of what measures one ought to take when swimming in a rough sea, and how to avoid being dashed against the rocks and on the rudders of ships. F 2 V.

Of the things carried by the water, that will make the greatest revolution which is of least size:

This happens because the great revolutions of eddies are infrequent in the currents of rivers and the small eddies are almost numberless, and large objects are only turned round by large eddies and not by small ones, whereas small objects revolve both in small eddies and large.

Of objects equal in length and breadth carried by the current of the waters, those will make fewest revolutions which are deepest.

This happens because these revolutions vary greatly from the surface to the bottom of the water, in which as many revolutions are produced as there is depth to cause them. Wherefore of necessity an object borne by the water when it buries itself deeply is buffeted by many revolutions at different degrees of altitude; and for this reason it remains in a state of hesitance and many times obeys none or if it obeys then it obeys the most powerful.

Of objects equal in shape and size, that which is buried deepest will obey least the revolutions of the water. F 3 r.

Book ten. Of the different recesses and roundnesses that exist in reservoirs, before the exits of the water from these reservoirs, with the varying rates of speed, sizes, depths and breadths; and the shapes of the holes, high or low, wide or narrow; and the walls thick or thin.

F 4 V.

Book nine. Of the water that passes through a reservoir, of which the walls are full of holes of various sizes, shapes and positions, at different heights, varying from the entrance to the exit and conversely; and so also the reservoir of different shapes, depths, lengths, and breadths; and the water more or less powerful and swift, great and small. F 5 r.

The flow and ebb is double in the same sheet of water, because it will be many times at the mouth of this sheet of water before there is a decrease in the great sheet of water; this occurs because the wave of the first flow runs strongly in the sheet of water, and during the time when this wave follows its impetus that at the mouth makes its ebb. Before the wave, penetrating into the neck, feels the ebb at this mouth of the sheet of water *g a*, the flow starts again at this mouth, and in this time the wave, which has penetrated into the neck, pauses, slackening its impetus in proportion as the second penetration by the second wave begins afresh. Thus so many of these waves enter the neck that the sheet of water is raised and its waters come back with impetus behind the ebb that recedes from this mouth, and [this ebb] does not penetrate farther in the third or fourth wave, so that the first water is not thrust out of the entrance. F 6 v.

In the big wide eddies, the water raises and uncovers the soil heaped up in its centre.

In the small eddies of water, the water bores down and makes a hollow in the centre of the eddy.

Of objects borne by the water upon its bed, the lighter makes a longer path in the same time.

A river does not remain uniform, for after the current it unloads shingle, and after this it produces another current, of which the movement is directed either to the bank or the centre or to as many different spots as there are different slopes of the mounds of shingle left at the bottom by the aforesaid currents. F 7 r.

The depth of the sheet of water which receives the fall of the water will always have the shape of a quarter of a hollow sphere, if the soil be of uniform resistance.

And this arises out of what has gone before, where it is stated that the straight course of the water is higher and swifter in the middle than on the sides; and the greater speed sends its fall more forward than does the slower speed. . . . F 7 v.

Given the depth of the fall of the water and its slant, with the power of the wheel that is its object, one seeks the height of the fall of this water in order to make itself equal to the power of the wheel.

The water that strikes upon the objects sometimes leaps up considerably, sometimes only a little, and sometimes it descends, and this arises from the objects being small or large, or the descent in front of these objects being greater or less, or from the current that strikes these objects being more or less powerful. F 8 v.

WATER—QUESTIONS

Why the eddies of the water are hollowed in the centre by their revolution.

Why the impressions produced on the surface of the water will maintain themselves for some time, on being carried by the course of the waters.

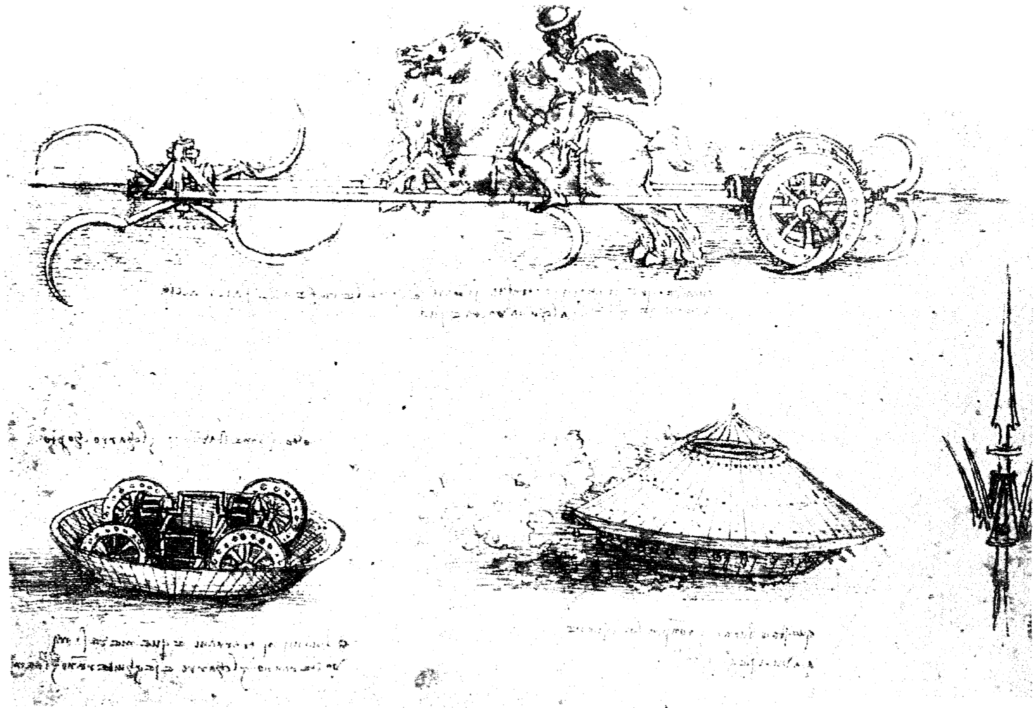
Why the movements of the impressions of the waters penetrate each other without change of their first shape.

Rule as to the measurements of water and what breadth, depth, and rapidity of movement a given space of current ought to have in a given time.

Given the resistance of a wheel and given the slant and descent in the fall of the water, one asks how great must its volume be to be equal to the said resistance.

Given the volume of the fall of the water and its length and slant, one asks whether the power of the wheel is equal to this power of the water.

Given the resistance of the wheel and the slant of the water and its volume, one asks the length of the fall. F 9 r.



WAR MACHINES
British Museum

OF THE MEASURING OF WATER AND IN HOW MANY WAYS IT CAN VARY

Water that pours out through the same-sized mouth may vary in extent in a greater or less degree in [various] ways, of which the first is that the surface of the water may be either a greater or less distance above the mouth through which it pours, the second that the water passes with greater or less speed beyond the bank where this mouth is made, the third that the side below the thickness of the mouth where the water passes may be either more or less slanting, the fourth in the variety of slant of the sides of this mouth, fifth in the thickness of the lip of this mouth, sixth as to the shape of the mouth, that is whether it be round or square, or rectangular or elongated, seventh according as this mouth is placed at a greater or less slant of bank in its length, eighth as this mouth is placed in a greater or less slant of bank in its height, ninth according as it is situated in the concave or convex parts of the bank, tenth as it may be placed towards the greater or less width of the canal, eleventh if the top of the canal has more speed at the top of the mouth or more slowness than elsewhere, twelfth if the bed have round bosses and hollows opposite to this mouth or higher or lower, thirteenth according to whether the water that passes through this mouth takes the wind or not, fourteenth if the water that falls out of this mouth falls through the air shut in on one side or on all except the front, fifteenth as the water that falls thus enclosed is deep within its vessel or shallow, sixteenth whether the enclosed water which falls makes a long fall or a short one; seventeenth whether the sides of the canal where this water descends are hollow or protuberant or straight or curving. F 9 V.

Of the eddies of water which frequently turn their revolving movement backwards:

Of the falling and the reflex eddies. The eddy sometimes grows in power and diminishes in diameter, and sometimes diminishes in strength and increases in diameter.

The first movement is when the water flows away by its base, as the water that forms the eddy becomes swifter when it is lower, because it has a greater weight of water above it and therefore becomes swifter;

and because the water pushes downwards more than upwards it restricts this void in the eddy more and more; and it bends because it directs itself to whether the sheet of water has its outlet. F 12 r.

Water with an uneven bed makes contrary movements from the surface to the bed. The unevenness in the beds of rivers springs from the bends in the banks or from substances that have fallen from these banks to their feet. F 12 v.

OF THE ACCIDENTAL EDDY

When the hand is turned in circular movement in a vase half-filled with water it causes an accidental eddy which will expose the bottom of this vase to the air, and when its motive power is at rest this eddy will follow the same movement but it will diminish continually until the end of the impetus imparted to it by its motive power. F 13 r.

OF THE HOLLOW AND UTILITY OF EDDIES OF WATER

The eddy with the deeper hollow will be that produced in water of swifter movement.

And that eddy will have a smaller hollow if it is produced in deeper water which has not the same movement but is slower.

And with water of equal speed that will keep a larger hollow where a greater depth of water turns with its movement.

This is said because many times the eddies are produced in a straight current in a great expanse of slowly moving water; and as this water is partly supported by the eddy which revolves in a thin coil between it and the air of the hollow, this lateral water being of great weight pushes upon the sides of the eddy where it is leaning and finding them weak compresses them. F 13 v.

[*Of eddies*]

If water higher than air acquires weight, as is shown in the seventh of the ninth, why is it that the water of the sides of the eddies is higher than the bottom of the eddy which up to this point is full of air.

You have the fourth of the seventh which proves that every heavy substance is only of weight along the line of its movement and in no other direction; and here you see very deep eddies after the manner of great pits in rivers, the sides of which are of water, which is everywhere higher than the air of this eddy; and these banks of water are without weight except by this line of their movement, during the time in which they possess the strength given them by their motive power.

What produces eddies and why some are hollow at the centre and others are not.

Whether water poured into the hollow of eddies would fill them or no, or would escape by the bottom and enter into the current at the side.

Which natural eddies are of considerable depth and which of slight depth; which change their position and which do not move; which while moving turn in an opposite direction and which keep their movement in one direction; which become duplicated and which do not; which unite in contrary movements. F 14 V.

OF WATERFALLS

Write first of the simple hollows made by the simple falls of water upon a bed of a uniform substance, and then upon a bed of various substances. Then with obstacles placed in the course that the water takes in its descent, then with obstacles in the place where it has struck, that is, upon its bed; then in its reflex movement, and first at the beginning of its fall. Then describe in what part of the edge of the sheet of water this water will take its course; and what substances will be carried away or deposited in different parts of the bed of this sheet of water; and what will be the speed or slowness of movement of the water in various parts of the surface, and so also from the surface to the bottom at various depths and breadths; and thus you will do as far as the bottom. F 15 V.

[*Movements of water*]

Of the parts of the same water that rises through the air at different angles, that which has least slant falls back nearer to where it started.

The rising motions of the water which it makes from the bottom to the surface of the sheet of water will never fall back towards the bottom, because not entering into the air and not acquiring weight they cannot penetrate to the bottom, by the seventh of the ninth.

The water always rises and descends with a disconnected movement of speed, and this is caused by the air that it penetrates and the air that is mingled with it. F 16 v.

OF THE EDDIES OF WATER

It is possible for there to be less depth underneath the current than before it or on the sides.

Let *o c n* be the current and *a* an eddy of double strength according to the ninth concerning eddies. Since in addition to its revolution it strikes against the bank and leaps up into the air, and falling back upon the rest of the water penetrates it and strikes and hollows out the bed in sudden chasm, for, in addition to the force of the blow, there is joined the spiral drilling made by the aforesaid revolution, by means of which what has been shaken by the blow is stirred up and carried away; and it becomes more powerful as it is more turbid.

And this is the most powerful method that can be made use of in order to dislodge and carry away the soil and so create a great chasm.

Beneath the current the bed will become raised when the course of this current dies in stagnant water.

By the sixth of the ninth—where the course of the water fails, there remains that which the water has brought. F 17 v.

Of a volume of water that has struck upon an object, the lower part is the first to strike the bottom and it is instantly reflected to the surface. That which is in the middle does not descend to the bottom, but encountering the first part reflected it strikes upon it, and is knocked and so it also is bent back in the same lines and revolutions.

And the two bodies of water when the lower encounters the higher unite and revolve together at their contact.

Of the water that falls into other water that which is nearest the centre of the fall slants most and that nearest the extremities is the straightest. F 18 v.

SURFACE WAVES

When water strikes other water at a considerable angle the part which strikes first is immediately bent back and delays, and that which succeeds to it veils it with a thin covering and runs swiftly upon that which first slackens and so it is then bent and slackens at the same spot as the foregoing. And the water that follows does the same upon it, and so in succession each new wave follows its course.

The turbid running water, if it is high at its start and at its entry into the sheet of water, flows for a considerable distance at the height of its first impetus before it buries itself or becomes mingled with the other water. F 19 V.

Definition of the half-cylindrical wave and what part of its volume has a greater or less slant, and how it commences and ends, and where it is more or less wide or more or less high or I would say deep; and the differences that there are in it when it is large or small or swift or slow.

The waters flow one above another without mingling for a long space, when their entrance in the sheet of water is higher and swifter in the one case than in the other. F 20 r.

Where the water has only slight movement the half-cylindrical waves will keep their direction when they intersect.

Where it is swifter they will curve.

And where the rates of speed are unequal their curves will vary towards the end. F 20 V.

Of the eddies one is slower at the centre than on the sides, another is swifter at the centre than on the sides; others there are which turn back in the opposite direction to their first movement.

That eddy is slower at the centre than on the sides which makes a great revolution, and this deposits a considerable quantity of matter in the centre of its circle and leaves it in the form of a mound.

The eddy which is swift at the centre of its revolution carries air and water in its base, which it hollows out and bores down after the fashion of a well. F 21 r.

Every impression of the water is maintained over a long space and this is so much the longer as it is swifter.

Write of the things worthy of remark that are found in water; and what revolutions they make when they are of different shapes and the water makes different revolutions. F 21 V.

Of the different rates of speed of currents from the surface of water to the bottom.

Of the different cross slants between the surface and the bottom.

Of the different currents on the surface of the waters.

Of the different currents on the bed of the rivers.

Of the different depths of the rivers.

Of the different shapes of the hills covered by the waters.

Of the different shapes of the hills uncovered by the waters.

Where the water is swift at the bottom and not above. Where the water is slow at the bottom and swift above.

Where it is slow below and above and swift in the middle. Where it is slow in the middle and swift below and above.

Where the water in the rivers stretches itself out and where it contracts. Where it bends and where it straightens itself.

Where it penetrates evenly in the expanses of rivers and where unevenly. Where it is low in the middle and high at the sides.

Where it is high in the middle and low at the sides.

Where the current goes straight in the middle of the stream. Where the current winds, throwing itself on to different sides.

Of the different slants in the descents of the water. F 23 v.

OF THE WATERS THAT CROSS ONE ANOTHER AT DIFFERENT ANGLES

Of the waters that cross at different angles in their reflex movements, and of those that cross on the summits of the waves; those that cross the descending wave and those that cross in the trough of the waves.

Some cross at different angles, great reflex movement with small reflex movement, and similarly a great wave with a small one, or falling movement with that in the valley or with reflex movement, small with large.

Sometimes there is reflex with falling movement, sometimes valley with wave, sometimes falling movement with reflex, small and large, and at different angles.

Sometimes rapid waters with slow, sometimes eddies with waves or valleys or reflexes, or the falling movements of water flowing along different lines crossing one another.

Courses by different lines one above the other.

Eddies with different movements which have to meet and enter into one another.

Lengths of different curves of eddies from the surface of the water to its bed as they intersect one another.

Intersection of falling and reflex eddies.

Of the waters that are interposed in any direction between the said accidents of the waters. F 24 r.

[*Books of the Treatise on Water*]

Book nine of the shapes of the eddies.

Book ten of the action of the eddies.

Book eleven of things that aid the eddies.

Book twelve of things that injure the eddies.

Book thirteen of the percussions of the waters one with another as they leap up within the air at different rates of speed.

Book of the waters that spring up within the air at different angles and with the same speed.

Book of the waters that spring up within the air and the different angles.

Water more slanting, striking that less slanting and more powerful and less deep.

Water less deep and more slanting and more powerful than the deeper and less slanting.

Shallow water driven through the air by greater power than the deeper water. F 24 v.

Of the waters falling through the air which intersect with various depths and lengths of movement and power.

The reflex movement will never be of the height of the beginning of the falling movement unless it strikes as does the wave on the rock of the sea. F 25 r.

[*Of the waves*]

In proportion as the waves of the sea are higher than the ordinary height of the surface of its water, so the bottoms of the valleys that lie between the waves are lower; and this is due to the fact that the great fall of the great waves creates the great hollows of the valleys.

F 25 v.

OF THE ELEMENT OF WATER

Here follows the proof of what is said on the opposite page:

I say that no part of the surface of water moves of itself unless it descends, therefore as the sphere of water has not the power to descend in any part of its surface, it follows from the first conception that it does not move of itself. And if you carefully consider each minute particle of this surface you will find it surrounded by other similar particles which are at an equal distance between them from the centre of the earth, and at the same distance from this centre is that particle which is surrounded by them; therefore, by the third conception, that particle of the water will not move of itself because it is surrounded by edges of equal height. And thus every circle formed of such particles makes itself a vessel for the particles enclosed within this circle, which vessel has the circle formed by its edges of equal height; and in this respect this particle resembles all the other similar ones of which the surface of the sphere of the water is composed. Of necessity it will be without movement of itself, and in consequence each being at equal height from the centre of the world, necessity makes their surface spherical, but it is not necessary that they should be spherical below, as reason and experience show.

That which is said of the surface of the water that borders on the air is understood to be said of the surface of the air that borders on the fire, which would be such as often to evaporate after the manner of clouds drawn by the heat of the sun, as does the water drawn through the air by the same heat in the form of clouds; and in the same way the fire drawn by a greater heat than its own, that is to say by the sun, it being proved in the sixth that it is warm by essence and not by virtue, as many would have it.

So having proved by the testimony of these spheres that the flexible elements are spherical, it is my purpose to investigate nature both in its universal aspect and in the particulars of each of its elements, and first of fire, then of air, and then of water. F 26 v.

Book thirty-two. Of the movement that fire makes when it penetrates the water at the bottom of the boiler:

It runs bubbling to the surface of this water by different ways and according to the movements that the water makes when struck by the penetration of the fire. By means of this experiment you can investigate the hot vapours which are exhaled from the earth and pass through the water, twisting themselves about because the water checks their movement, vapours which afterwards penetrate through the air in straighter movements.

And this experiment you will make with a square glass vessel, keeping your eye at about the centre of one of these walls; and in the boiling water with slow movement you may drop a few grains of panic-grass because by means of the movement of these grains you can quickly know the movement of the water that carries them with it. And from this experiment you will be able to proceed to investigate many beautiful movements which result from one element penetrating into another. F 34 v.

BOOK FORTY-TWO. OF RAIN

The water that falls from the cloud is sometimes dissolved into such minute particles that by reason of the friction that it has with the air it cannot divide the air but seems to change itself into air. Sometimes in descending it multiplies, because it finds the minutest particles of water which by reason of their lightness were of slow descent, and becomes incorporated with them, and at every stage of its descent acquires a new quantity of water. Sometimes the winds bend the rain and so cause its descent to be slanting, and for this reason the descent becomes slow and protracted, and it frequently happens that it is converted into such fine particles that it can no longer descend and so remains in the air.

[*Treatise on water*]

Write how the clouds are formed and how they dissolve, and what it is that causes vapour to rise from the water of the earth into the air, and the cause of mists and of the air becoming thickened, and why it appears more blue or less blue at one time than at another. Write in the same way of the regions of the air and the cause of snow and hail, and how water contracts and becomes hard in the form of ice, and of the new shapes that the snow forms in the air, and of the trees in cold countries with the new shapes of the leaves, and of the pinnacles of ice and hoar-frost that form new shapes of plants with strange leaves, the hoar-frost serving almost as the dew ready to nourish and sustain the said leaves. F 35 r.

No surface of water that borders upon the air will ever be lower than that of the sea.

The wave that the motive power makes before it in the air or between the surface and the bed of the water is in the shape of a half sphere.

The wave made by the motive power on the surface of the water is in the shape of a half-circle, and towards the bottom it has the shape of a quarter-circle.

Why the movement made by the motive power on the surface of the water makes a wave before it, and does not do so when it moves between the surface of the water and its bed. What one asks occurs because the water of the surface borders on the air, whereas the water that is between the surface of the water and its bed borders on the water that is above and the water that is below. F 41 r.

Of the water that falls from the weirs of rivers, that part will have its straight course shut in which has the most powerful fall:

This comes about because water with a powerful fall hollows out the soil of the spot on which it strikes and deposits it where its course is more feeble than beneath the reflex movement of the water; this as it moves towards the sky becomes more feeble with each degree of its movement until at last it loses all its power.

And as in this reflex action its power ebbs it lets fall below it all the things of weight taken from the spot where it has struck, and after this inundation the water becomes lowered and finds itself shut in between the matter which it formerly carried and the bank from which it has descended.

Of the waters that descend in torrents from the weirs of rivers only that will preserve its straight course beyond this torrent of which the fall was feeblest and slowest.

This happens because that which moves slowly strikes feebly, and therefore it follows that it only raises itself a little from the bed on which it strikes, and in consequence deposits but little in the reflex movement of the water. And this is why after this deluge the bank here remains low, and all the water that falls follows its course where the bank is lower, and consequently the straight course of all the water of the river will remain with the water that has a feeble fall. F 42 v.

Of the things borne by the water which have part of themselves in the air and part in the water:

If a thing is borne by the water being half in the water and half in the air, and the air moves with a speed equal to the speed of the water, then this movable thing will be in the first stage of swiftness of movement.

If the air is slower than the movement of the water which moves in the same direction as the air, the movement of the movable thing will be slower than if these movements of air and water were equal, and it will be so much slower in proportion as these movements of air and water are more different.

If the movement of the air is swifter than that of the water[1] which moves in the same direction, then this movement of the object will become more rapid, and the more so as this air is swifter than the water.[1]

If the movement of the air against the course of the water is of equal speed to that of this water against the air, the movable thing will follow the course of the water if it has more contact with the water than with the air: it will do the contrary if it has more contact with the air than with the water. F 43 v.

How a leaf is whirled about along different lines in the depth of the water:

This movable thing revolves along different lines, high and low, turning itself over or not turning over, and doing the same in the width of the water which moves it. And this springs from the different movements of the water with its different slanting and eddying courses. Here one may place objects of different shapes, *and one will have made a good experiment in* [2] . . . by the leaves of the trees which are borne in considerable quantities from the surface to the depth of the flowing and transparent waters. F 44 r.

[1] MS. *aria*.
[2] Words erased in MS.

THE ORDER OF THE BOOK

To set forth the conditions of the waters that spring forth within the air, and their percussions made with different degrees of power, quantity, length of movements and variety of slant, I will institute a comparison between the four principal winds, namely: north, south, east and west; and with these conditions I shall equip myself to give information as to the aforesaid movements of the water within the air; as a result this description will be briefer and more expeditious.

F 45 r.

These are the four ways in which the waters moving in the same manner penetrate one another with lines that slant towards the centre of the earth.

These four demonstrations are sufficient to prove the four principal effects that the waters produce as they strike one another within the air. Of which the first is that in which the more slanting penetrates the less slanting, and penetrates it in part and carries with it the part that has been struck.

In the second demonstration the less slanting penetrates the more slanting in part and carries with it the part that has been struck. In the third demonstration the more slanting water carries away with it entirely the less slanting water. The fourth does the opposite, in that the less slanting water carries away with it entirely the more slanting.

F 45 v.

If the earth were [not] spherical no part of it would be uncovered by the sphere of the water.

You will never find a flat piece of the earth without the water upon it being of convex shape standing in the middle of this level surface. And this water will never move towards the extremities of this plain. Therefore upon a surface that is absolutely flat there may be water of varying degrees of depth.

It is impossible to find any flat part in the surface of any very great expanse of water.

The deep recesses in the ocean bed are everlasting, the summits of the mountains are the contrary: it follows that the earth is spherical and all covered with water and that it will be inhabitable.

An object which is carried by the course of the water . . . in the course of less power: if it is slanting below it will move towards the bottom, and so it will move according to the direction of its slant.

Of the objects carried between two currents of water only that one will proceed without being turned upside down which is in the middle of two currents of equal movement.

But that will be in continual revolution over and over which is in the middle of two unequal currents.

An object will not make any lateral revolution when it moves between currents equal in movement; and so conversely. F 52 V.

Of the movement of a thing that slants irregularly in water which has a regular current: it will proceed to turn continually when below the surface of the water, and that in which the slant is regular will not make any turn.

When the upper part of the straight side of the object and the lower part are struck by an equal current this object will make a lateral revolution. F 53 V.

[*The percussion of water*]

All water after it has struck against an object is divided into four different and principal movements, namely right and left, high and low; and the low movement causes injury to its bed.

Of the four principal movements which water makes as it divides in its reflex action, that will be more rapid which is reflected at a more acute angle. F 54 r.

OF THINGS CARRIED BY THE WATER

Of the things carried by the course of the waters that which has a larger part of itself in the air responds to the movement of the air more than to that of the water; and so conversely that which has a larger part of itself in the water will follow the course of this water more than that of the air.

See in the windings of the canals where the water is swifter below, in the middle, and above, and of this make a book.

The pipe by which water is drawn to a height receives less damage than that pipe along which water is driven; and this is due to the fact that in the first case the motive power is above and in the second it is below.

Where the water is most rapid, it wears away most the bed on which it rubs.

Where the water is most shut in, it becomes most rapid and in its passage wears away its bed most. F 65 r.

The object always changes the order of the nature of the waves that have been commenced.

The current *a b* has one order and the object which receives its percussion throws it over completely and changes it to another figure.

If you wish to form a correct impression of all the shapes of the waves and the courses of the waters, observe the clear water where it is shallow beneath the rays of the sun, and you will see, by means of this sun, all the shadows and lights of the said waves and of the things carried by the water.

The sphere of the water increases and decreases sensibly or insensibly, according to the greater or less, more universal or less universal deluges of the waters given back to this sphere of the water.

F 65 v.

EDDIES

Eddies are always the intermingling of two streams of water, that is, the falling and the reflex.

All the water which in the currents of the rivers tarries behind the objects in these currents has no other exit than by contact with the aforesaid currents.

The eddies which turn back are always those of the swiftest water. And the eddies that are turned in the direction that the stream is flowing are those of the water which tarries in the stream's course.

Here the law of the waters in their eddies does not fail, because the water that becomes slow, turns back, and makes the eddies in the opposite direction to its movement, as do the eddies of the swiftest water. And for this reason these eddies, whether of the slow or of the rapid water, mingle together and redouble their power; but not entirely because the slow eddy in mingling with the swift becomes swifter than at first, and the swift eddy as it embraces and unites with that which is slower acquires slowness.

The hollow in the swift waters caused by the submersion of the eddies will point towards the approach of the waters, and in the slow waters it will point in the direction in which they are flowing.

F 66 r.

COMMENCEMENT OF THE BOOK

A drop is that which does not detach itself from the rest of the water unless the power of its weight is more than its adhesion to the water with which it is joined.

That drop is formed more slowly which has a slower movement of water at its creation.

All the movements made on the surface of water are also made at each successive stage of its depth, and likewise in each part of its length; and this is learnt from the grasses that grow on the beds of the streams. F 66 v.

Water that falls in the air separates itself with difficulty from its bulk, and the sign of this is found in the curve that it produces and the winding of one of its parts round the other, between which the film of water is interposed. F 67 r.

If the earth covered by the sphere of the water is more or less heavy than if it were not so covered:

I reply that the heavy substance weighs more which is in the middle of the lighter.

Therefore the earth which is covered by air is heavier than that which is covered by water.

[*Diagram*]

I say:—the centre of gravity of the pyramid being placed at the centre of the earth, it will change its centre of gravity if it is subsequently covered in part by the sphere of the water, and I give an example with two cylindrical weights that are equal and similar, of which one is half in the water and the other entirely in the water: I say that that which is half out of the water is the heavier, as has been proved.

Suppose there to be a straight line equal to the diameter of the sphere of the water, which touches the surface of the sphere of water in the centre of its length. One asks what is the difference between each of the miles of the descent which the surface of this sphere makes below the said line. F 69 r.

[*Centre of the earth and watery sphere*]

Because the centre of the natural gravity of the earth ought to be in the centre of the world the earth is always growing lighter in some part, and the part that becomes lighter pushes upwards, and submerges as much of the opposite part as is necessary for it to join the centre of its aforesaid gravity to the centre of the world; and the sphere of the water keeps its surface steadily equidistant from the centre of the world.

Where the sun is straight above, the earth grows light; covered by the air, the waters and the snows have been lacking to it, and on the opposite side the rains and the snows have made the earth heavy again and drive it towards the centre of the world, and thrust the parts that have become lightened to a greater distance from this centre; so therefore the sphere of this water preserves an equality of distance from the centre of its sphere but not of gravity.

Water poured in the air at a concave angle becomes spread out in a sheet, and it remains spread out in a sheet more on the side of the angle where this water makes more contact; and on the opposite side the sheet of water will leap up and make its union at first in the form of an open sheath. F 70 r.

[*Water of the sea and of rivers*]

The sea beneath the equinox is raised by the heat of the sun, and acquires movement over every part of the hill or portion of the water that rises in order to give equality and restore perfection to its sphere.

If an outlet of water with sixteen ounces descent in each mile yields me sixteen measures of water, how much will the same outlet afford with eight ounces descent per mile?

The revolutions of the cross-eddies acquire size and slowness at each stage of their length.

The convulsions of the reflex movements of the water at the bottom of rivers destroy the circling movements of the longitudinal eddies.

The water of the sea and of the turbid rivers is heavier than the other waters, and as a consequence offers more resistance to the weights it carries.

The water of the sea offers more resistance because the weight of the salt that is mixed with it is liquefied, and it is inseparable from it without the heat that dries up the water; but the turbid part of the water is separated from it by heat and when the water is at rest. F 70 v.

[*Movement of water in the air and in the water*]

The movement that water makes in the air follows for some distance the line of the sides of the small holes through which it descends. It is not thus with the discontinuous quantity that the stone shows itself to be when thrown by the circular movement of the man's arm; this follows the straight movement; which the water does not do on account of it being spread out in a sheet, for this in a long space of movement collects all the parts of the water together.

The impressions of the movements made by the water within the water are more permanent than the impressions that the water makes within the air; and this takes place because water within water is devoid of weight, as is proved in the fifth, but only the impetus weighs and this moves this water that has no weight until it is itself consumed.

The impressions of the movements of water are more permanent when the water carried by the impetus enters into a sheet of water (*pelago*) with slower movement, and conversely.

The impressions made by the water within the air are destroyed in the first movement that they make towards the earth, because the impetus is consumed in the natural movement that is produced in the water. F 71 r.

OF THE MOVEMENTS OF WATER

The falls of water that intersect in the air become filled with air in their reflex movement.

Of the falls of water which strike each other within the air being of equal thickness, that which descends from a higher part of its reservoir will join itself to the course of that which is lower and will complete its course with it.

Falling water which then runs over terraces breaks its bed very much at the end of these terraces.

This proceeds from the fact that when the current of the water reaches the last stage of these terraces it falls and raises itself from the bottom, burying itself so much the more as its fall is deeper, because the fall is more powerful in great descents than in lesser ones.

All water, when it strikes the bottom or upon another object, divides and runs in different directions.

All water, when it surges up, divides at the surface and runs in different directions, and so much the more as the sheet of water is more tranquil. F 71 v.

The simple movements of the waters are those which act simply with their simple movement of whatever kind it may be.

Composite movements are created by different movements and these are very powerful in different functions.

The wave is slower at the summit than upon its sides.

The falling movement is more rapid than the reflex.

Joined together, the greatest and the least slowness of the waves, that is of the wave in itself with its sides and summits, become equal to the common course of their stream, and this is to be adduced in the conclusions, that is to say to prove them. F 72 r.

[*Of the raising of water in nature and by artifice*]

If the water which gushes forth from the high summits of the mountains comes from the sea, the weight of which drives it up there so that it is higher than these mountains, why has this portion of water the capacity of raising itself to so great a height, and of penetrating the earth with such difficulty and length of time, while it has not been granted to the rest of the element of water to do the same, although this borders on the air which would not be able to resist it and so prevent the whole from rising to the same height as the aforesaid part?

You who have found such an invention must needs return to the study of natural things, for you will be found lacking in cognate knowledge, and of this you have made great provision by means of the property of the friar of which you have come into possession [?].[1]

[1] Ravaisson-Mollien says: 'Cette phrase signifie peut-être: Si tu as trouvé à inventer une imitation de l'élévation de l'eau dans la Nature, aux cimes des monts, en ayant cru beaucoup t'instruire à cet égard avec le fonds de livres, dessins, etc., du frère [moine] un tel, que tu possèdes, cette instruction-là te trouvera bientôt en défaut, et il te faudra de nouveau étudier les choses de la Nature.'

Water falling into a channel of width equal to the width of the water that falls will make a deep hollow within the surface of the water.

Water falling into [a channel] where the width is greater than the said fall will not make a very great hollow in the surface of the water, on account of the eddies, which cause the water to bend in the hollow caused by this fall.

Water which clears away the bottom on which it hurls itself rapidly or slowly in all its width, depth or narrowness, its seething mass being tossed back by the bed of the watery expanse, is in part caught up again to the surface of the water, there to make its various falling and reflex movements, in part returns to where was its first fall, burying itself there with it and then returning up in lateral eddies, and in part falling back in the middle of the seething mass and spreading itself out with slow movement round the centre of its fall.

F 72 v. and r.

[*Movements of water*]

Between the current and the eddy is the sand.

Between the sand and the eddy is a smooth valley where the eddy turns.

In the eddy are pieces of timber and other light things.

If the air is motionless an object borne on the surface of the water will be slower than one that is below its surface.

Where the water issues forth by a level bed beneath the sluices it hollows out the bed before and behind these sluices. F 77 r.

THINGS CARRIED IN RIVERS

A wide object borne by the current of the river between the surface and the bed of the river, if it should meet with water that is slower than that which bears it and should find itself at that time slanting in the direction of the approaching river, will immediately leap from the bed to the surface of the water; and if this slant is pointing in the opposite direction to the course of the water then in encountering the slow current it will suddenly precipitate itself towards the bottom; and if this slant looks to the right or left of the breadth of the stream it will throw itself to this right or left side of the stream and so will continue in any direction. F 78 r.

SEA-MUD AND FOSSILS

If the mountains had not remained in great part uncovered by the waters, the courses of the rivers would not have been able to carry so much mud into the sea as exists at a great elevation, mingled with the animals which have been enclosed by it.

The revolutions of the reflex water in returning to the current of its river penetrate it more in its lower parts than on its surface; and this proceeds from the fact that the current, by the seventh, is swifter above than below, and is in consequence more powerful above, and therefore less penetrated by the percussion of this reflex water above than below.

The eddies formed by the percussion of the reflex water in the course of the falling water are of two kinds, of which one is produced towards the bottom and revolves vertically through the length of the stream, the other is upon the surface and revolves right and left through the breadth of the stream. The lower is produced by the falling down again of the seething mass towards the bottom, and that on the surface by the revolving movement striking into the surface current. F 78 v.

Water turns before falling water like the wheel of a mill. F 81 r.

Of the surfaces surrounding the water that is poured through the air from an expanse of water, and also what the water does in these surfaces.

Of the movements of the things that have fallen with the water which moves in the air, and also what they do in this expanse of water.

Of the things that float upon the middle water, and how they become submerged when they find themselves between the centre of the middle water and the fall, and they become submerged together with this fall which takes place in the expanse of water, and strike against the bottom and break in pieces.

Write therefore all the effects of the things that become submerged in any extremity of this middle water, which always submerges its extremities because it is in the centre of all the reflex movements towards the bottom of its expanse of water. F 81 v.

Of the earth. Every heavy substance tends to descend, and the lofty things will not retain their height but with time they will all descend, and thus in time the earth will become a sphere, and as a consequence will be completely covered with water, and the underground channels will remain without movement.

Of the convex wave. If the wave created by the fall of the water of a canal of uniform breadth and depth will be of long movement or no.

Of the concave wave. If the concave wave created by the water that falls abruptly from the open canal under a sluice will be of long movement in a canal of uniform breadth and depth. F 84 r.

Water which runs through a canal of uniform emptiness and fills all its first smooth part, will fill all the other straight and slanting parts and will move with equal swiftness.

The movements of the heavy elements are not to the centre in order to go to this centre, but because the medium in which they are cannot resist them, and when they find resistance in their element this body no longer has weight and does not seek to penetrate to the centre.

Water in air weighs and descends by the shortest path. It divides and opens the air which is below its centre of gravity with all its parts equally, and it does not divide the air that is upon its sides because it is not situated above it. And because of this it makes a hollow in the air of very short length until it reaches that which resists it; and as this resistance is that of water the water that falls through the air no longer seeks to go the centre, because it no longer divides the water as it did with the air; therefore the heavy substance moves downwards where it meets with no resistance, and not in order to go to the centre.
F 86 v.

Write first of all water in each of its movements, then describe all its beds and the substances in them, adducing always the propositions as to the aforesaid waters, and let the order be good as otherwise the work will be in confusion.

Describe all the shapes that water assumes, from its largest to its smallest wave, and their causes. F 87 v.

BOOK NINE. OF THE ACCIDENTAL RISINGS OF WATER

If with a sluice the larger body of water is divided by the narrower and the movement of the water is from the narrower to the larger, the water which rises under the sluice will leap on to the larger water, and by its falling back it will hollow the bed of the canal in several places with different leaps. F 88 r.

[*Treatise on water*]

Describe what water does in each defined instance between its surface and the bottom. And what part of the water is slower or more rapid.

Of the lateral objects placed upon the banks of winding rivers.

Of the intersections that the waves make one with another on being bent back by the opposite banks of the rivers.

Of the elevation of the waves formed by the intersection of other cylindrical waves. F 89 r.

Of the various breadths of the transversal interpositions set in the middle of the breadths of rivers.

Of the various projections of the lateral objects set upon the banks of rivers.

Of the different slants placed in the middle of the widths of rivers.

Of the different juxtapositions of the fronts of the lateral objects placed upon the banks of rivers. F 89 v.

[*Book of the treatise on water*]

If the cylindrical wave shall strike the eddies produced about one of the extended banks, these pent-up eddies will be contracted and acquire great power to excavate beneath the bank and cause it to fall in.

Order of the book.

Put at the beginning what a river can do of equal depth and slant of bed on its bank, where lie objects of various kinds. Then place these objects two by two. Then place them to face the opposite bank, in the same variety, and describe what the waters do when they intersect one another in the centre of the stream, and the obstacle they afford to the water reflected by the opposite bank. And then describe what each does in its bed, that is how it rises and settles itself.

The side of the wave when it makes its rapid falling movement is the end of the slow reflex movement. It follows that the movement of the valley of the wave is swift and the crest of the wave is slow.

F 90 V.

CURRENTS OF RIVERS

If the course of the river is contracted on one of its sides it produces a half-cylindrical wave which is swift; and the eddies which are produced between the contracted bank and the cylindrical wave occasion the laying bare and crumbling away of this contracted bank.

If the banks should contract equally on each side of the current and opposite, then the cylindrical waves will intersect, and after this intersection they will descend and strike upon the bank and cause it to fall headlong.

But if the contraction of one bank should be lower than that of the other, then the upper cylindrical wave can enter under the lower.

Here it is necessary, in the commentary, to define the distances of the contractions of the banks and their breadths. F 91 r.

[*Of canals, rivers and eddies*]

The bank which is made to curve inwards in order to give greater breadth to the canal is the cause of the sudden forming of an eddy, and this bores down and makes a deep hole at the base of the bank and so becomes the cause of its fall.

This is proved by the first of the third, which shows that the river in acquiring sudden breadth of space acquires also sudden breadth of water, and the water thus widened comes also to lower itself in depth; and so it suddenly creates a current which hurls itself upon the bank where it has been widened, and striking it divides itself into two eddies, one of which (the more powerful, as *c b a*) in order to be enclosed throws itself vigorously straight towards the bottom; and by the ninth which says that as the eddy will be most easily penetrated which has the lips of its mouth least slanting, it will have them quite straight.

Water brings about the fall of that bank of which the canal acquires a sudden breadth.

If the canal gains on each side sudden breadth it produces eddies on each side; if these are united at the centre of the breadth of this canal it will make of itself a sudden and great depth.

All these figures have to result from experience. F 91 v.

[*Cylindrical waves*]

The more the half-cylindrical wave moves the more it descends, and the more it spreads itself out the swifter it becomes.

When there are two unequal cylindrical waves of which the larger comes into existence before the smaller, this smaller wave intersects the larger and passes above it. And this happens because the larger which is created first, when it is opposite to the smaller, is spread out and lowered, and the lesser which strikes it, being high, strikes the lowness of the greater one, and not finding any obstacle as high as itself runs over it and falls headlong on the opposite side and follows its initial impetus.

But if the lesser of the unequal cylindrical waves starts higher in the river than the greater, then this greater follows its natural course, and the lesser follows the course of the greater. F 92 r.

If the cylindrical waves clash and do not intersect as far as the centre, the middle part which clashes leaps back and passes above the part that does not clash.

When two cylindrical waves of equal size and power clash absolutely they each turn back completely without any penetration one of the other.

But if the cylindrical waves are unequal in size, neither the larger nor the smaller will observe their law, because the larger does not bend and the lesser unites with the larger.

But if when the waves are equal the rise of the one is before that of the other, their blows will not be delivered with equal power; consequently the course of the second will bend before that of the first. F 92 v.

Water that moves between a bank and a straight smooth bed will not make a wave of any kind.

What is thus stated takes place because a wave is only created by a reflex movement, and the reflex movement arises from the percussion of the falling movement which is made upon the particular object at the bottom or the sides of the canal; and if in these places there are no particular objects then by what has been said it will not create any wave, this water being made by minute upward movements which only raise themselves a little from the bottom, so that they do not make waves by coming to the surface.

The simple half-cylindrical wave is formed upon some small object that is joined to the bank; the water that strikes it there makes a long wave in the shape of a half-column which takes its course slantwise towards the opposite bank, and dies there and is reborn.

Let *a* be the object, placed upon the bank *a o* of the canal *n o m p*.

I say that the water which strikes upon this object will make a wave which by its being continually reformed will also make itself continuous; and it would be always so if it were not interrupted by the common course of the water of the canal, which all strikes on this wave and drives it unceasingly in every stage of its length, so that at the end it directs it according to its ordinary course. F 93 V.

[*Currents and falls of water*]

In water of ordinary speed the middle water will have tiny ripples.

The water that is interposed between the mean of the surface and its bed is not of the nature of the mean; whereas this mean of the surface receives the percussion of the falling and the reflex; for the one and the other to be within the boundary falls upon the other water, making percussion of the air as of a heavy thing, and as a heavy thing it penetrates within the other water struck by it.

The water falls at first, rises up again, and raises itself with its semi-cylindrical wave above the semi-cylindrical wave opposite which made its fall more slanting. F 94 r.

[*The current of rivers*]

Water that descends in a straight river moves always by a slanting course, from the centre to the opposite banks and from these opposite banks to the centre of the river. This is proved by the ninth of this where it is stated:—The course of straight rivers is always higher in the centre of their width and upon the sides than it is between the centre of their width and these sides. And this was proved by the seventh in which it was stated:—The water of straight rivers never flows in a straight line because it is so much swifter as its obstruction is farther removed from the banks. And this was confirmed where I said:—Where the falling movement is impeded there the reflex movement is created; and by the tenth of this: Always between the falling and the reflex movement is the maximum depression in the expanse of the rivers; and by the eleventh:—After the last height of the reflex water there is produced the beginning of the falling movement; and by the twelfth:—The falling movement of the waters does not change into the reflex movement without percussion against the bed or the bank of the river. Where the water strikes the bed or the bank of the river there the soil of the bed or the bank of the river becomes raised.

Always under the falling movement the bed of the river becomes raised and its height is restored under the reflex movement.

The lateral slants of the waters which move continually in straight rivers are of a greater or less degree [of slant] according as these waters have a more or less rapid current. G 14 V.

[*Density of water—fresh and salt*]

HOW THE OCEAN DOES NOT PENETRATE WITHIN THE EARTH

The Ocean does not penetrate within the earth, and this we learn from the many and varied springs of fresh water which in various places of this Ocean penetrate from the bottom to its surface. The same thing also is shown us by the wells, made at a distance of more than a mile from the said Ocean, which are filled with fresh water; and this takes place because the fresh water is lighter than the salt water and as a consequence more penetrating.

Which weighs more, water that is frozen or water that is not frozen?

Fresh water penetrates more into salt water than salt water does into fresh water.

That fresh water penetrates farther into salt water than salt water does into fresh is shown us by a thin cloth, dry and old, that hangs with its opposite ends at an equal depth in two different bodies of water, of which the surfaces are equally low; you will then see how the fresh water will raise itself so much higher up on this piece of cloth than the salt water, as it is lighter than it. G 38 R.

OF THE MOVEMENT OF A RIVER WHICH SHOOTS FORTH SUDDENLY UPON ITS DRY BED

The course that the water takes when issuing from a lake into a dry river-bed is so much slower or swifter as the river is wider or more confined or in a more level position in one place than in another.

By what is set forth the flow and ebb of the sea which enters from the Ocean into the Mediterranean, and of the rivers that contend with it, raises their waters so much the more or less as the sea is more or less confined. G 48 r.

WHY WATER IS SALT

Pliny says in his second book, in the hundred and third chapter, that the water of the sea is salt because the heat of the sun scorches and dries up the moisture and sucks it up, and thereby greatly increases the salt savour of the sea.

But this cannot be admitted, because if the saltness of the sea were caused by the heat of the sun there is no doubt that the lakes and pools and marshes would be more salt in proportion as their waters have less movement and depth, but, on the contrary, experience shows us that the waters of these marshes are entirely free from saltness. It is also stated by Pliny in the same chapter that this saltness might arise because, after the subtraction of every sweet and tenuous portion such as the heat readily draws to itself, the more bitter and coarser portion will be left behind, and in consequence the water on the surface is sweeter than that at the bottom. But this is contradicted by the reasons given above, whence it follows that the same thing would happen with marshes and other tracts of water which become dried up by the heat. It has also been said that the saltness of the sea is the sweat of the earth, but to this we may reply that then all the springs of water which penetrate through the earth would be salt.

The conclusion therefore is that the saltness of the sea is due to the numerous springs of water, which in penetrating the earth find the salt mines, and dissolving parts of these carry them away with them to the Ocean, and to the other seas from whence they are never lifted by the clouds which produce the rivers. So the sea would be more salt in our times than it has ever been at any time previously; and if it were argued by the adversary that in an infinite course of time the sea would either become dried up or congealed into salt, to this I reply that the salt is restored to the earth by the setting free of the earth which is raised up together with the salt it has acquired, and the rivers restore it to the earth over which they flow.

But—to express this better—if it be granted that the world is everlasting it must needs be that its population also will be everlasting; and that therefore the human race has perpetually been and will be consumers of salt; and if the whole mass of the earth were composed of salt it would not suffice for human food. And for this reason we are forced to conclude either that the substance of the salt is everlasting as is the world, or that it dies and is renewed together with the men who consume it. But since experience teaches us that it does not die, as is shown from the fact of fire not consuming it, and from water becoming more salt in proportion as it is dissolved in it, and from the fact that when water evaporates the original quantity of salt remains, there must needs pass through human bodies as urine or perspiration or the other excretions that are found there as much salt as is brought every year into the cities. And therefore we may say that the rains which penetrate through the earth are what carry back underneath the foundations of cities and their peoples through the passages of the earth the saltness taken from the sea; and that the change in the position of the sea which was over all the mountains has left the salt in the mines that are to be found in these mountains.

As a third and last reason we may say that salt is in all created things; and we may learn this from passing water through ashes and the refuse of things which have been burnt, and from the urine of animals and the excretions which proceed from their bodies, and the earth into which by corruption all things are changed.

G 48 v. and 49 r.

OF THE CHANGES OF THE EARTH[1]

The subterranean courses of the waters like those which are made between the air and the earth are those which unceasingly wear away and deepen the beds of their courses.

[1] MS. *della vibratio della terra.*

The soil carried away by the rivers is deposited in the ultimate parts of their courses; or rather the soil carried away by the high courses of the rivers is deposited in the ultimate descents of their movements.

Where fresh water is rising to the surface of the sea it is a manifest portent of the creation of an island which will be uncovered more slowly or more rapidly as the quantity of the water that rises is less or greater in amount. And this island is produced by the quantity of earth or deposit of stones made by the subterranean course of the water in the places through which it flows. G 49 v.

HOW WATER CONSUMES AS IT FALLS

The falls that the waters make at their banks always wear away the bases of these banks and cause them to fall headlong on their foundations. This is proved:—if the height of the bank *a c* from which falls the water *a n*, striking and consuming the place struck *m n c*, be the centre of the percussion upon which are divided the reflex movements *n m o* and *n c b*, which in each direction consume the bank that is chafed by their revolving movements, then as the banks find themselves thus consumed their supports collapse on the side on which their prop fails.

The water which falls from *a b* to *n m* will proceed to deepen all the bed from where it falls as far as the lowest level of the place where it falls, from *a b* to *c d*. G 50 v.

WHETHER THE WATER CAN RISE FROM THE SEA TO THE TOPS OF THE MOUNTAINS

The water of the sea cannot penetrate from the roots to the summits of the mountains which border upon it but only raises itself as far as the aridity of the mountain[1] draws it. And if on the contrary the rain which penetrates from the summit of the mountain to its roots which border on the sea, descends and softens the opposite slope of the same mountain, and draws the water continually as does the syphon which pours through its longest side, it must be this which draws up to a height the water of the sea; thus if *s n* were the surface of the sea and

[1] MS. *monte*. So Richter. Ravaisson-Mollien reads *mondo*.

the rain descends from the summit of the mountain *a* to *n* on one side of it and descends on the other side from *a* to *m*, this without doubt would be the method of distillation of a filter or as happens through the tube called a syphon; and the water which has softened the mountain by the great rain which descends from the two opposite sides would constantly attract the rain *a n* on its longest side together with the water of the sea, if the side of the mountain *a m* were longer than the side *a n*; but this cannot be because no part of the earth that is not submerged by the ocean can be lower than this ocean. G 70 r.

[*With drawings*]

These convolutions must be made with coloured water falling blindly into clear water. G 90 v.

Running water has within itself an infinite number of movements which are greater or less than its principal course.

This is proved by the things supported within two streams of water which are equal to the water in weight. If the waters are clear they show well the true movement of the waters that conducts them, because sometimes the fall of the wave towards the bottom bears them with it so that they strike upon this bottom; and they would be reflected back with it to the surface of the water if the floating body were spherical; but it frequently happens that the wave does not bear them back, because they are wider or narrower in one direction than in the other, and being thus irregular in shape they are struck upon the side that is largest by another reflex wave which proceeds to roll over and over this movable thing which moves wherever it is carried, its movement being sometimes swift and sometimes slow, and turning sometimes to right and sometimes to left, at one instant upwards at another downwards, turning over and turning back upon itself, now in one direction and now in another, obeying all the forces that have power to move it, and in the struggles carried on by these moving forces going always as the booty of the victor. G 93 r.

There can be no flow and ebb unless several rivers discharge themselves in the same expanse of water. G 95 r.

In the course of the year the amount of the water that rises will be as great as of that which descends in the rivers and the air. H 29 v.

[*Course of rivers*]

All the things which are lighter than sand will be left in the lower part of the river underneath the beginning of the fall of the wave.

Where the water has least movement the surface of the bottom will be of the finest mud or sand.

Where the course of turbid water meanders among the gnarled roots of thickets it will deposit much sand or mud through the many twists of its eddies. H 30 r.

OF THE COURSES OF MILLS

The water which gives less weight to its course is swifter.

The water which is swifter drives its wheel faster.

That gives less weight to its course which is straighter.

The water of the mills ought to strike the blades of the wheels at right angles.

That water which flows with less slant will strike the wheel farther from the perpendicular of its fall.

That water which strikes farther from the perpendicular of its fall gives a less blow. H 30 v.

The wave created by the percussion of water upon the bed of a river will make a movement from below contrary to that from above.

The wave is slower at the end of its elevation than at any other part.

The parts of the wave which move most swiftly will be near the end of its fall.

The sand remains higher underneath the highest part of the wave than under its lower part. H 31 r.

When a stone is thrown into still water it will create ripples that expand equally if the water is of uniform depth.

If two stones are thrown one near to the other within the space of a braccio, the circles of the water will increase equally one within the other without the one destroying the other.

But if the bottom is not level the circles will not expand in uniform movement except on the surface.

When an object of long shape is thrown into water it will create an oval undulation.

A round object thrown into running water will create an oval undulation in two movements. H 31 v.

Where the water is higher it has more weight upon its bed and its course is more undulating.

That part of the bed or of the bank which projects with the sharpest angles into the straight course of the waters suffers most damage in the flow of the water. H 35 v.

Water which strikes on an angle deepens the former sides. H 36 r.

Every part of the surface of the water desires to be situated at an equal distance from the centre of the elements, and if one part of the surface be raised above another this so happens because of the contrary movements which are taking place between it and the bottom. H 37 r.

Where the current is in the centre of the full stream the ridge will not be between the point of union of the eddies and of where the water rebounds; it is all deep.

The large pebbles remain in the deepest part of the current. H 37 v.

Where the channel of the water grows narrower it digs its bed deeper and flows more swiftly. H 38 r.

Iron which receives continually the impact of flowing water never rusts but is consumed by being burnished. H 39 r.

In proportion as the object dividing the water is more distant from the surface it leaves less sand behind it. H 39 v.

Where one body of water joins another at a sharp angle it will make a great depth. H 40 v.

[*Of things carried by the water*]

Where the water makes less movement there when laden it deposits its weight. H 46 v.

If a long object uniform in weight and thickness finds itself in the middle of an even descent, its length will move according to the length of the course of the water.

STUDY OF HANDS
Royal Library, Windsor

When a long object moves in a channel midway between the middle and the contact of the bank it will move slantwise.

The long object which is nearer to the side than to the centre will proceed to revolve upon the water. H 47 r.

Where water has less movement there it deposits its weight more lightly.

The eddies of water after it has struck the ground at an angle turn in contrary movement. H 47 v.

Water will be in perpetual movement if its surface is not equidistant from the centre of the earth.

Sand and other light objects follow and obey the twists and turns of the eddies of the water while the large stones move in a straight line. H 50 [2] r.

Water which falls into smooth water causes it to become slanting, consequently its descent becomes swifter. H 50 [2] v.

Measure the height of the falling water and multiply it by the height to which you wish to raise it, and as many times as the extent of the fall of the water enters into the height to which it has been raised, so many times is it thinner than that which rises; and this is the last and greatest amount that can be raised. H 51 [3] v.

Water which rises continually because of the movement of other water will be so much the thinner as that which moves it is of greater length. H 52 [4] r.

Turbid water does more harm to the banks than clear water, and more at the base than at the top, because it is heavier and thicker. H 52 [4] v.

The line of the water which has the greater movement breaks that of the lesser movement and buries itself beneath it.

That part of the sand which is nearest to the impact of the falling water will be finer than the rest.

The large shingle will be farthest away from the blow. H 53 [5] r.

I ask whether the water which emerges underneath comes from the surface or no.

The first depth will be where the sum of the blow of the second water makes its way into the course of the eddies; the lesser where the second base is, is where the revolving water encounters it in its course.
H 53 [5] v.

After the descent of water that which was above remains below; the lower part becomes changed into the upper part.

After the most rapid descent of the water the lower part remains of more rapid movement than the upper part. H 54 [6] r.

Of waters that flow upon beds of equal slant that will have the less depth which has the greater breadth.

Of waters that flow between banks of equal breadth that will have less depth which possesses the more rapid course. H 54 [6] v.

Water in its movement drags with it the air which borders on it.

And the bed offers more resistance: this is why it moves more on the surface than at the bottom.

All the upper part of the water which finds itself at the beginning of its fall will be lower than the other after this fall. H 55 [7] r.

Water which flows in falls of equal slant will move more strongly at the bottom of the canal than at its surface. H 56 [8] v.

Waters which fall from the same level with an equal slant in an equal length of movement will be of equal swiftness. H 58 [10] v.

Of waters which fall from the same level by channels of equal slant, that will have the swifter course which has the greater length.

Of waters which fall the same distance from the same level, that will be slower which is longer. H 59 [11] r.

The percussion of the water upon the wheel will be at the highest degree of its power when it strikes within equal angles.

The percussion made between equal angles will be of the greatest power when the current of the water and the movement of the wheel are in the same direction. H 63 [15] r.

The sand moved by two light currents of water settles itself upon the steep bank in a square ridge. H 63 [15] v.

Water which has struck against a round body will create equal hollows beyond the sides of this body.

Gravel dug up by the blows of the water will settle where the movements made by the blows meet.

That face of the triangle which is interposed between more nearly equal angles in the course of the water will be the cause of a great hollow in the water that strikes there. H 64 [16] r.

Water which moves by a uniform slant will be swifter at the surface than at the bottom.

The wave that is caused by a blow will be higher at the beginning than in the middle.

Waves that are caused by the wind will be higher in the middle than at the beginning; that is the fourth [will be higher] than the third. H 67 [19] v.

These back-currents eat away the banks of the canals; you will therefore make screens of wood to extend for the whole of their impact. H 68 [20] r.

[*Movement of water*]

Water which exceeds the general depth and breadth of rivers moves in contrary movement.

The wave of the water will swell between the cause of the movement and its end.

Water which moves by reason of the undulation of the wind will make a contrary movement at the bottom to that at the surface.

Water does not weigh less crosswise than in the line of its perpendicular.

Every movement of liquid weighs more in the direction in which through a hole of equal size its vase empties itself more rapidly; the centre of the bottom of the vase receives a greater weight of water than any other place. H 68 [20] v.

The free movement made by the upper part of water will not make angles of any kind except in the percussion.

All the upper lines made by the movement of water are curved.

The wave follows the movement of the air which touches it.

The object enclosed between the air and the wave does not follow the movement of the one or the other.

The water that is expelled from the spot which the vessel occupies weighs as much as all the remainder of the ship which displaces it.
H 69 [21] r.

Streams of water equal in current and angle of descent which move one against the other, penetrate and pass through each other without turning aside from their natural course. H 69 [21] v.

Water which moves against motionless water attacks and destroys its bank.

The water with the greater movement penetrates and traverses the lesser movement of other water, like air. H 70 [22] r.

The line made by the course of water after its percussion leaps back at equal angles. H 71 [23] r.

The farther water is away from its bed the freer will it be in its natural movement. H 72 [24] r.

Where the water has a stronger current the shingle is larger. All the detached shingle will turn its largest side slantwise against the course of the water. H 74 [26] v.

All light things gather together in the centre of the eddies that is at the bottom. H 75 [27] r.

Every portion of water desires its parts to be as the whole element, equally distant from its centre. H 76 [28] r.

The water which flows near the bed of the stream between the banks will be slower than the rest because of the percussions made by the eddies. H 77 [29] v.

[*Error as to buying water*]

You who buy water by the ounce know that you may greatly deceive yourselves. In fact if you take an ounce in stagnant water and an ounce in flowing water, against the hole of your ounce, an ounce near the surface, one near the bottom, one across the current . . .

In proportion as the natural movement separates itself from its cause so it becomes more rapid. H 78 [30] r.

That wheel of the water will be better turned when the water that turns it does not leap back after its percussion.

The blow will be of the greatest force when the movement which causes it is straighter and longer. H 79 [31] v.

[*Sand and water*]

All the hollows of the furrows visible in the sand will be between equal angles, according to the movement of the water. H 80 [32] r.

OF SAND

The wave is less sloping and of slower movement in its rise than in its descent. H 81 [33] r.

The surface of the water of rivers desires to be equidistant from the centre; as it leaps it weighs down and consumes the bed because it grows thicker in the course of its intersections and increases in weight as it enters the air, and in consequence falls and bursts through the bed. H 81 [33] v. and 82 [34] r.

In water that has no movement the leaves that ranged through every part of the water rest upon its bed. H 82 [34] r.

The back-currents which are formed in the midst of the expanse of the falling water are situated between the leap of the water and its banks. H 82 [34] r.

The back-currents made by the water after the expense of its fall will be between the surface and the bottom, between the upper and the lower part. H 83 [35] r.

If the beds of two canals are of equal slant and breadth, and contain an equal volume of water, and one is restricted to two thirds of its breadth in the middle of its course and the other is uniform in breadth, I ask which will discharge more water.

Water that falls into other water strikes against its bed and raises itself farther in the air than does the general surface, and then falls back and lessens its bounds. H 83 [35] v.

The lines of the water as it leaps after its percussion will not be in a straight course but will bend in a curve. H 84 [36] r.

A straight canal of uniform depth and slant will make within a short time a deeper hollow in its centre than near the bank.

The water in the middle of straight canals flows more rapidly than it does at the sides.

Where the water has more movement it is lighter if it is of the same height.

Water which has been pent up will burst the bank and the bottom after its fall. H 84 [36] v.

Every canal of water of uniform declivity, depth and breadth, which is pent up for a certain space, will burst its bed and its bank after the passage of this restricted area.

This is due to the fact that where water is pent up it rises behind this barrier and after passing through this narrow place it presses on furiously; as it descends it comes upon the water below which does not flow and so it receives a check. After this it follows the line of its descent and goes to the bottom and burrows there and turns with a circular movement towards the banks, and hollowing these out from below it makes them fall in ruin, as is shown in the drawing above. H 85 [37] r.

[*With drawing*]

Water below obeys its natural course less than that above.

This comes about because the water that borders on the air is not made heavy by any weight, so that simply and without any restraint it obeys its natural course *c d*.

That below is weighted and pressed and acts as is shown at *a b*. See that as it forms an angle at *a* and above at *c* it cannot form anything but a curved line.

All the waters some distance below the surface intersect after their percussion. H 85 [37] v.

That water will turn in contrary course which exceeds the general breadth and depth of the rivers.

Waters of equal breadth and unequal depth will be of equal movement on the surface.

Among the currents of water of equal slant that which is the straightest will be the swiftest. H 87 [39] r.

Water which exceeds in depth or breadth the general breadth and depth of the river will turn against its first course. H 87 [39] v.

[*Method*]

Remember when discoursing about water to adduce first experience and then reason. H 90 [42] r.

Of streams of water equal in length, breadth and declivity, the swiftest will be the one of greatest depth. H 92 [44] v.

All the movements of streams of water which are equal in depth and declivity will be more swift at the surface than at the bottom, and more at the centre than at the sides. H 93 [45] r.

Water, which is the vital humour of the terrestrial machine, moves by its own natural heat. H 95 [47 v.] r.

[*The circulation of water*]

The water which from the lowest depths of the sea entering by the force of its mover is driven to the high summits of the mountains, there finding the severed veins, hurls itself headlong and returns by the shortest way to the depths of the sea; and again it raises itself through the ramification of its veins and again falls back, and thus, coming and going, sometimes high and sometimes low, inwards and outwards, it revolves with natural or accidental movement after the manner of a screw, while the water that is poured away through its severed branches and falls back upon itself rises again through its courses and returns to the same points of descent. H 101 [42 r.] v.

Where three currents of water meet together there will be created a sudden depth, for they rise and acquire weight and then movement with force, and this breaks in the percussion that it makes upon the bottom. I 61 [13] v.

[*Of the fall of a river*]

If the bottom of the bed of the river from which the water hurls itself is hollow in the centre, the water which moves from the sides and directs itself towards this centre will raise itself before falling.

If the river as it flows strikes against some rock, it will leap up, and the place that it strikes in its fall will be of the nature of a well.

I 62 [14] r.

If the rock in a river projects above and divides the course of the water which rejoins after this rock, the interval that is found to exist between the rock and the reunion of the water will be the place where the sand becomes deposited.

But if the rock that divides the course of the waters is covered by the flowing waters only in its lower parts, the water that passes above will fall behind it and form a hollow at its feet and cause it to turn; and the water that falls headlong into this chasm turns in vortex upwards and downwards, for the uniting of the two streams of water which had been divided by the rock does not suffer the water immediately to pursue its journey. I 67 [19] v.

Every natural and continuous movement desires to preserve its course on the line of its inception, that is however its locality varies it proceeds according to its beginning.

This movement aforesaid occurs in the course of rivers, which always attack and destroy whatever opposes the direct line of their course.

But if these rivers were straight, with equal breadth, depth and slant, you would find that with each degree of movement they would acquire degrees of speed.

Consequently if there is a change or difference in their slant there is a difference in their course; and where there is less inequality in breadth they become deeper; and given an equal slant, where they are wider they become slower. Therefore the waters which desire a straight course, and to make themselves swifter at each stage of their movement, finding the places through which they pass wider and deeper become slower and break the bed or the bank. I 68 [20] r.

WATER AND AIR

The movement of the rebound of water is swifter than that of the percussion when the water that strikes is much mingled with the air.

I 68 [20] v.

For the air is capable of being compressed, and the more it is compressed the more it has weight within the other air; and the greater its weight the greater its percussion against its object, as is seen with the winds which are constrained from great breadth to pass through a narrow defile of the mountains: if there were no opening above them they would not fill up the spaces of the things in front of them, but they are able to expand above with great facility because there are great spaces between the hills . . . and below readily, and the wind flies easily towards the height. Remember how Augustus made a vow in Gaul to the wind Cirrius because for just such an impetus he had to lose his army, and there he made a temple. I 68 [20] v., 69 [21] r. and v.

Water will leap up far higher than it has fallen, through the violent movement caused by the air which finds itself shut in within the bubbles of the water, and which afterwards rises and floats like bells upon the surface of the water. Returning to the place where it strikes, the water is again submerged by the blow, so that the air finds itself hemmed in between the water which drives it down and that which encounters it, and being pressed upon with such fury and violence suddenly bursts through the water which serves it as a covering, and like a thunderbolt emerging from the clouds so this air emerges from the water carrying with it a part of the water[1] which previously formed its covering. I 69 [21] v.

[*Water in canals*]

When water in some part of its passage through a narrow canal becomes wider it immediately becomes shallow and swifter because it finds a slope where it moves vigorously. And along the course it has commenced it directs itself to the foot of its dike and strikes it.

After which percussion it turns upwards and proceeds with a whirling movement hollowing out the foundation of the bank until it returns upwards. And this process of hollowing it out gives it the shape of the hull of a ship, narrow at the commencement and the end and in the centre deep and wide. I 70 [22] r.

[*Eddies*]

Here arise the bubblings or wellings up of water in the middle of

[1] MS. has *aria,* air.

the higher eddies. And it may be asked whether the movement of the eddies starts because it runs towards the percussion of the water, which is lower than in any other adjacent part; or because the thrust of the water that flows in the centre of the breadth of the surface is that which as it strikes the other waters raises them and makes a hill with the other water, and then returns towards its entry in the expanse of water; or if the water struck by the other waters in its stream and pressed by it gushes up and leaps back to the place from which the current comes.

I 71 [23] r.

BEGINNING OF THE BOOK OF WATER

The name *pelago* (sea, large lake) is applied to an area large and deep in form in which the waters lie with little movement. *Gorgo* (whirlpool) is of the same nature as the *pelago* except for a certain difference, and this is that the waters that enter into the *pelago* do so without percussions while those of the *gorgo* are made up of great falls and bubblings up and surgings occasioned by the continuous revolutions of the waters. *Fiume* (river) is that which occupies the site of the lowest part of the valleys and which flows continuously. A torrent is that which flows only with rains: it also makes its way in the low parts of the valleys and joins itself to the rivers.

Canal is the term applied to waters regulated within their banks by human aid. *Fonti* (sources) is the name given to the birthplaces of rivers. *Argine* (bank) is that which with its abrupt height withstands the widening of rivers canals and torrents. The *ripa* (bank) is higher than the *argine*. The *riva* (shore) is lower than the *argine*. The *spiaggia* (beach) is among the lowest of the parts which form boundaries with the waters. *Lago* (lake) is that in which the waters of the rivers assume great width. *Paludi* (marshes) are stagnant waters. *Grotte* (caves) are hollows formed in the banks of rivers by the course of the river; their length follows the line of the course of the water; they have some depth and also find their way under the foundations of the bank, losing their shape as they near the end of their course. Caverns are of the shape of ovens which enter far beneath the bank, and the waters in them are in a state of wild turmoil and are constantly increasing.

Pozzi (wells) are the sudden depths of rivers. *Stagni* (pools) are the

places of refuge for the waters of floods or storms, their beds being firm and thick so that the soil can neither drink in nor dry up these waters. *Baratri* (chasms) are also places where the water suddenly becomes deep. *Procelle* (storms) are tempests of water. *Polulamenti e surgimenti* (bubblings and wellings up) are the beginnings of the waters; but the former come from below upwards and the latter merely in transverse movement which falls from some grotto. *Sommergere* (submersion) is understood to refer to things which enter under the water; *intersegatione dacque* (intersection of waters) takes place when one river cuts the other.[1]
I 72 [24] r. and v.

When the general courses of the rivers are contracted, as they issue from the valleys and enter amid the defiles of the mountains, the water will heap itself up in its wide part; and it will make great descent and movement through the said contracting of the mountains, and after passing the middle of this contracted part it will make a great hollow, and then having entered again in the broad part it will lack depth, in just such proportion as the wide part increases in such a way that the waters become of equal course.

And the said depth will be lacking after the leap of the waters, because it will become filled up with shingle beneath the greater altitude of the leap of the said waters.

If the fall is of the same width as the river, the water that strikes the bottom will leap up and then fall back again by each line that departs from the centre of the surging mass, and the farther they descend from this surging mass the more they spread out. And part is moved by the course of the stream, and as a consequence it is necessary for it to make three movements, each of which consumes a considerable portion of the foot of the bank.

For that which descends from the summit of the surging mass throws itself towards the bottom, and since such descent is slanting it acquires a movement towards the bottom of the bank; and as this descent follows in part the general movement of the river, this surging mass falls with a threefold descending movement, one proceeding downwards, another towards the bank, another towards the course of the river. And all three consume the base of the bank, by reason of the

[1] A list of words is added, descriptive of movement of water.

great displacement occasioned by so much impetus; for if the river were to flow for a long way hugging the bank it would be able to find some stone which at some spot would protect a piece of this bank near to it; but this movement proceeds downward towards the bottom, forward towards the bank, downward towards the course of the stream, in such a way that each stone is struck by three different movements and on three different sides.

From which it follows that if the soil is friable it crumbles away in a short time. I 74 [26] v., 75 [27] r.

[*Of the movement of water—bubbles*]

When one sees mountains rising in the running waters, rising in the form of bubbles, it serves as a sign of the great depth from which these bubbles spring after the percussion made by the water upon the bottom; and by the speed of its rebound it bores through and penetrates the other water and then turns towards the surface of the running water and passes through it, rising up in this way; thereafter acquiring weight it loses its first impetus and falls down again by each line round its centre, and returns again towards its bed. I 76 [28] v.

CURRENTS

Of the difference water makes in its course if its sides strike on a strand, a bank, or other water, that is in passing by a piece of stagnant water or running water crosswise.

One should also observe what differences there are in rivers if they fall upon beds of different natures, namely upon stone or earth, or tufa or clay, sand or mud, or stagnant or running water, and this crosswise or slanting or opposite, or by the same line as the water itself, that is by the line of the same current but slower or swifter than that which it strikes, or more level or more slanting.

OF EDDIES

One asks why the percussion of water within water makes lines of circular movements and eddies, and its leap is not straight as is that other which beats upon its shores and banks.

Why bubbles are not continuous when the falls of the water are:

The reason is that the water which flows above after falling is swifter than that which flows below; and when that below precipitates itself in some chasm it raises itself towards the surface with almost the same impetus, and sometimes subdues and overcomes the water that flows above and sometimes is subdued by it.

Being thus in a state of equilibrium as to its power of movement sometimes one conquers and sometimes the other.

I 77 [29] r. and v.

Things lighter than water do not follow the course of the rebound and intersection of the water, but pass along the centre of its current or near the parts as they are found at the entrance of the currents, and are not impeded unless by equal pressure, because if the right wave of the rebound meets with the left, it is necessary, if they are of equal power, that the place of their percussion be thrown back equally.

Consequently things in this place which move upon the water, not being driven more by one percussion than by the other remain in the same line of current. But if one of the forces of the wave be greater than the other, that is by the swiftness of its current, I do not mean force arising from a greater quantity of water, for if the one water was much less thick than the other this would not matter: for let us suppose one body of water to be less than double the other in volume and to acquire double its speed; now since these bodies of water clashing together are of equal size in their contact, as I have proved in the third of the fifth, the larger being a square braccio and the lesser of a half braccio, the lesser does not strike the greater unless it is in its half, and in the same way the greater strikes the lesser with its half, so that the contacts made by the percussions are equal in quantity and unequal in that the power is double, the speed of the one being double that of the other.

OF THE EDDIES

Sometimes there are many eddies which have a great current of water in the middle of them, and the more they approach the end of the current the greater they are. These are created on the surface by the waters that turn back after the percussion that they make in the most rapid current, for the front portions of these waters, being themselves slow, on being struck by the swift movement, are suddenly transformed into the said speed. Consequently the water which touches them behind is attached and drawn by force, and torn away from the other, so that it turns all in succession, one (wave) following the other with a like swiftness of movement, if it were not that such current at first cannot receive it so that at any rate it does not rise above it, and as this cannot be it is necessary for it to turn back and consume in itself these swift movements. From that time the said eddies with various revolving movements proceed to consume the impetus that has been begun. And they do not remain in the same positions, but after they have been formed thus, turning, they are borne by the impetus of the water in the same shape, in which they come to make two movements; the one is made in itself by its own revolution, the other as it follows the course of the water which is carrying it along all the time that it is destroying it. I 78 [30] r. and v., 79 [31] r.

[*Air and water*]

The water which by a slight movement encloses, a little way below its surface, the air which is submerged with it, turns with a slight impetus out of the surface, carrying with it such covering of water that being of equal weight with this air it stands above it in the form of a half-spherical figure.

But if this air is submerged with impetus it comes back out of the water with fury for the length of the movement made beneath the water; and pressed by its weight it leaps out of the water, breaks its surface with its impetus and flows on with straight course after the manner of wind emerging from bellows which discharges itself in a stream through the air; and therefore it does not, as does the former as it floats upon the water, remain enveloped in its surface.

I 80 [32] v.

How all the air which leaps back with the water does not remain on the surface but by its impetus submerges itself anew amid the revolutions of the waters:

How the movements of the waters among the other waters are not obliged to move more by a straight line than a curved one, and how after leaping back as they wished these waters are not obliged to be at rest, but in order to return to a low place and with a revolving movement they go attending the course of the river until they have discharged the air that is enclosed within them on the surface of the sheet of water. I 81 [33] r.

[*Of water flowing into water*]

BEND OF CURRENT

If the entry of the water into the sheet of water (pelago) is of circular shape the concavity of its base will be of the form of a crescent, receiving the shingle within its circumference or within the two horns of this figure.

I ask whether if the current should make some bend it will become hollow at the bottom or in the middle or above, and the same thing as regards the leaps which follow afterwards against the bank of the rivers, the bed being of uniform substance, and also as to the bank where it is raised, where it leans and the methods of effecting its repair.

I 81 [33] v.

[*Of falling water*]

I ask as to the shape that water assumes in the different slants of its descent in each of its falls, and what shape the concavity will have when the water strikes upon a bed of uniform substance; and I ask as to the shape the shingle will take which is left after the percussion of each of these, and the remedies when they are injured. I 82 [34] r.

HOW TO STRAIGHTEN RIVERS WHEN THEY HAVE A SLOW COURSE

Because the straighter the river the swifter will its course be, and the more vigorously will it gnaw and consume the bank and its bed, it is therefore necessary either to enlarge these rivers considerably or to send them through many twistings and turnings or to divide them into a number of branches.

And if the river through many twistings and turnings becomes slow and marshy through its many detours you ought then to straighten it, in such a way that the waters acquire sufficient movement and do not cause destruction to the banks or dikes; and if there should be depth near to some dike you ought to fill up the spot with gabions together with fascines and shingle, so that it may not become hollowed out by movement under the dike, and so by causing it to crumble the river may afterwards proceed to make a bend in your land or villa and there straighten its course. I 82 [34] v.

[*Of the earth carried by water*]

When the water in the floods commences to find a place where it can flow, it begins with its feeble inundation to strip and carry away the lightest things, and deposits them where its course becomes feeble, then as it grows it carries away the heavier things such as sand, and carries them over the former things and there leaves them, and even though the water should not increase, by the mere fact of its continuance it proceeds by degrees to carry away the things from the place where it flows; but by reason of their weight it cannot carry them so far forward as the first lighter things, and if it then carries away the heavier things it deposits them proportionately near to the spot from whence it took them.

How to restore the soil to the places that have been uncovered and stripped bare by the courses of the waters on a hill or mountain or in sandy places.

For the rains, or to provide an outlet for other waters, one ought to construct canals or mouths of rivers, for the places where they pass in so great current that they tend to become turbid by reason of the earth they carry with them and to be changed; then when they are at the place where you wish that they rid themselves of the soil, these canals of water are divided into many small channels of water, after the manner of furrows, and their violence is lessened and they grow clear again. I 83 [35] r.

[*Of flowing water*]

Where the river is constricted, it will have its bed stripped bare of earth, and the stones or tufa will remain uncovered by the soil.

Where the river widens, the small stones and the sand will be deposited.

Where the river widens considerably, there will be discharged the mud or the ooze and bits of timber and other light things.

Where several currents of water run together, there will instantly be formed a hollow that will be navigable.

Where the waters separate, the sand and ooze will be deposited and the bed will be raised in the shape of the half of a ship inverted.

Beneath the rebounds of the water, there will be formed hills of sand or stones.

Beneath the repercussions, that which rests under the rebound will become raised.

Where the water finds the place higher, which forms an obstacle beneath it, it makes a greater and higher wave and then forms a deeper hollow. I 83 [35] v.

Where you find much sand you will find at the end of it in front or behind shingle or bare tufa.

Sand is discharged when waters meet in their course, for in such a spot nothing can remain that offers resistance to a current so reinforced; light waves drop their sand at the sides of the said current, and the sand as the current becomes less swift forms a cover to the shingle.

Sometimes the lesser floods carry branches covered with leaves from the plains and deposit them in their small movements, and then, becoming stronger, heap sand upon the edges of these branches and still increasing carry there shingle and tall large stones. I 84 [36] r.

[*The rebounds of water*]

The rebounds that water makes which rise through the percussion of water which has fallen upon other water, are not carried between the equal angles of its percussion, but will leap to the surface by the shortest way, through the air that was submerged together with the water. I 84 [36] v.

If a stone is thrown into still water it will form circles equidistant from their centre; but if into a moving river the circles formed will lengthen out and be almost oval in shape, and will travel on together with their centre away from the spot where it was first made, following the course of the [stream] . . . I 87 [39] r.

OF WAVES

The waves are of [twelve] kinds, of which the first is made in the upper parts of the waters; the second is made above and below by the same path; the third is made above and below by contrary paths, and is not in the centre; the fourth is made so that from its centre upwards it runs in one direction and from this centre downwards it makes the opposite movement; the fifth flows downwards and not upwards; the sixth flows downwards and above has a contrary movement; the seventh is that of the submersions of waters by means of a spring that enters into the earth; the eighth is that of the submersions by means of eddies which are narrow above and wide below; the ninth is that of the eddies wide at the surface and narrow at the base; the tenth is of cylindrical eddies; the eleventh of eddies that bend in regular curves[1]; the twelfth is of the slanting eddies. Make here all the waves together, and all the movements by themselves, and all the eddies by themselves. Arrange thus the series in order separated one from the other. And so also the rebounds of how many kinds they are in themselves and also the falls. And set down the differences that there are in turbid waters, in their movements and percussions, and those that are clear; and similarly in waters that are violent and those that are sluggish; in those that are swollen and those that are shallow; and between the fury of pent-up rivers and those with a wide course; and of those that run over great stones or small ones or sand or tufa; and of those that fall from a height striking upon different stones with various leaps and bounds, and of those that fall by a straight path touching and resting upon a level bed; and of those that fall from a great height alone through the air; and of those that fall through the air in shapes that are round or thin or wide or separated or united. And then write down the natures of all the percussions: on the surface, in the centre, and at the bottom, and of their different slants, and the different natures of the objects and different shapes of the objects.

And if you give movement to a sheet of water, whether by opening its sluices above, or in the middle, or below, show the differences that are caused by it falling or moving on the surface, and what effect it makes in entering with such fall upon the ground or in stagnant water, and how that by which it is moved at first maintains itself in a channel level or uneven, and how it produces all at once eddies and their recesses, as one sees in the basins of Milan, and the nature of the sudden rush of the rivers, and so also with those that grow little by little; of the waters also that cannot in the great floods pass through the arches

[1] MS. *dequal nacuita.*

of the bridges which surmount them, and how the water that passes through these arches increases the impetus through having a great weight above. 87 [39] v., 88 [40] r. and v.

[*The water of mills*]

I ask whether if the impetus of the waters that turn the mills creates a protuberance either across above or below near the place of percussion, this percussion will have the same force as if this water ran in a straight line. I 89 [41] r.

OF WATER

Rivers when straight flow with a much greater impetus in the centre of their breadth than they do at their sides.

When the water has struck on the sides of rivers with equal percussion, if it find a part of the river narrower it will leap towards the middle of the river and these waves will make a new percussion between themselves; as a consequence they will return again towards the banks, equally, and that water of conical shape, which is enclosed between the first percussion made upon the bank and the second made in the centre of the stream, will slacken at its base and be swift near to its crest. Striking the bottom they will afterwards rise equally to the height of the intersection; but always that of the centre will be swifter than that which leaps back.

Water which moves along an equal breadth of river and on an equal bed will have as many different thicknesses as there are different slants in the bed where it runs; and by as much as it is swifter in one place than another so proportionately it will be more shallow.

I 105 [57] v., 106 [58] r.

OF MOVEMENT

Water which falls from the height of a fathom will never return to the same height except in small drops, which will leap much higher because the motion of leaping back will be much more rapid than that of the descents. In fact when the water falls it buries with it a great quantity of air, and after the (other) water has been struck it leaps back towards its surface with a force which creates a movement almost as rapid as was that of the descent; but not actually so for the reason given in the second of the seventh, where it is stated that the movement of the rebound will never be so swift as was the descent of the substance which rebounds; or thus:—a succeeding rebound will never be equal to that which precedes it. So that in consequence the rebound which the water makes proceeds from the base where it has been created, almost with the speed of the descent that has given it birth; and in addition to this there is added to it a second momentum which augments this motion, namely that of the air that is submerged by the fall of the water. This air clothed around with water bounds up with fury and leaps into its element like wind driven by the bellows; it carries with it the last of the water which is close to the surface, and by such an increase causes it to leap up much farther than its nature demanded.

I 108 [60] v., 109 [61] r.

The farther the circular wave is removed from its cause the slower will it become. I 114 [66] r.

[*The meeting of water-courses*]

If the courses of two lines of water which cross each other in the middle or in a part of their river-beds pass either the one into the other or the one over the other, do they then each leap back after the percussion? Certainly they leap, because it is impossible for the two bodies to pass one through the other.

But after the two bodies have clashed together they will widen themselves at their point of contact, and after having struck they will recoil to an equal distance from the centre of the percussion. And that body which goes upwards follows its nature, and the other body below the centre of the impact which would wish to go downwards and cannot, increases that above. I 114 [66] v.

EXPERIMENT OF THE REBOUNDS OF WATER IN A LEVEL CHANNEL

Make one side of the channel of glass and the remainder of wood; and let the water that strikes there have millet or fragments of papyrus mixed in it, so that one can see the course of the water better from their movements. And when you have made the experiment of these rebounds fill the bed with sand mixed with small shingle; then smooth this bed and make the water rebound upon it; and watch where it rises and where it settles down.

Then make the bank on the wooden side of mud, and watch its effects through the glass, and make it again in flowing water.

I 115 [67] r.

[*Movements of water*]

If the water was a quantity endowed with sense[1] as it is a continuous one, the movement that it makes between the extreme elevations and depressions of its waves would be unequal.

In effect the part that rises acquires degrees of slowness in each degree of movement, in such a way that at its greatest elevation it is in the extreme stage of slowness.

And afterwards in descending it acquires degrees of speed in every degree of movement, so that at its lowest depth it acquires greater movement; therefore the resistance that ends its descent is that which receives the hurt, and that which ends the height of its elevation has no hurt.

But if the quantity is continuous: the continuous quantity has equal movements when its river is of equal size and depth, because being all united together it is necessary that in all the parts of its movement each part draws and is drawn, pushes and is pushed, or drives and is driven. And it is necessary that this be with equal movement and power; and if it were not so the water would multiply more where it was slowest and would fail where it had most movement.

I 115 [67] v., 116 [68] r.

Where the water divides it rises; and afterwards as it falls down again it strengthens its course by the increased descent that follows.

Where the waters join they rise; and then the near movement that follows becomes slow. I 116 [68]

When in the courses of rivers there are two currents of water, commencing the one far from the other, which meet in a place where they clash together, they will rise up after this percussion, and their bed will be but little consumed because they depart from it; and afterwards they will fall back again as they separate, and fall asunder, and falling back

[1] MS. *disscreta.*

again they will strike and scrape upon their bed. By reason then of this percussion, which beats and scrapes the bed with its movement, a depth will be produced there; and this happens in the great currents of rivers.

I 117 [69] r.

[*The height and depth of the waves*]

OF THE SUMMIT OF THE WAVES

The greatest elevation of the waves will not wear away its bed beneath itself; in effect it touches it but little, by the fifth of the sixth which says that everything weighs by the line of its movement; from which we may say that this wave moves towards the air that flies from its percussion and weighs towards the air. If however the amount of friction is slight, it will have but little force and will consume the bed but little.

HOW WAVES ATTAIN THEIR GREATEST DEPTH

Whatever obstacle forms the chief cause in breaking the straight course of the water will be most consumed and displaced by it.

Therefore we may say that if the air were the cause why the straightness of the elevation of the wave is broken it would be consumed by this percussion of water. But this air is not the cause of the breaking of such a course; the only cause of it is the force which the water acquires as it emerges from its element. And it would relax its pace in such a position if it were a sensitive quantity, but being as it is a continuous quantity it is necessary that one body of water pushes and the other draws, because they are united. I 117 [69] v.

If the water moves more swiftly in the falling of the wave than in its rising, and at what point this water delays most.

The water that moves in the formation of the waves will find itself of as great speed during its ascent as that of its descent, and it will have as much in the middle of its lowest depth as that of its greatest height. And if it was not of equal movement it would not be of equal depth or breadth; and if however it was of equal length and depth but not of equal movement it would form a great height in the place where it slackened most. I 118 [70] r.

The water flows more strongly at the sides of a covered rock than above it and after it has passed it, and for this reason it twists the waves made by its rebounds, producing on its surface crescent-shaped figures. I 123 [75] r.

[*The different sorts of rebounds of water*]

The rebounds of the waters are of two kinds, that is they are formed from two causes; one is that of the lumps of the bed on which the water passes, the other is when the parts of the water that strike against the lumpy parts of the bank leap back to the opposite bank. These masses of water on striking leap back to the opposite bank and press and drive themselves upon the first wave that they meet, and swelling leap towards the sky; and each flies equally from the place where it has struck, until another wave drives it back and afterwards another drives it forward.

So in succession they fill the surface of the rivers with a trellis pattern, always raising themselves to the positions of the above-mentioned percussions. I 127 [79] v.

[*Rule as to rebounds: experiment*]

I ask concerning the rebound: if the first rebound is ten braccia tell me how far will the second be. Dye the ball so that it marks the spot where it strikes upon the marble or other hard substance, study the position of each of the rebounds in succession, and so deduce the rule.
I 128 [80] r.

If you throw sawdust down into a running stream, you will be able to observe where the water turned upside down after striking against the banks throws this sawdust back towards the centre of the stream, and also the revolutions of the water and where other water either joins it or separates from it; and many other things. K 1 r.

WATER AND NATURE

Water is nature's carter, it transforms the soil and carries to . . . a great part . . . double. K 2 r.

RIVERS

Simple movement: Many rivers there are that increase their waters at every state of movement without loss.

Simple movement: Many there are that lose without ever acquiring.

Composite movement: And there are a considerable number which acquire more than they lose.

Composite movement: And a considerable number lose more than they acquire. K 60 [11] v.

I have written in how many ways water hollows out the bottom, and in how many ways it deposits earth upon the bottom. And the same of the banks: where it raises them and where it forms them, and in how many ways it hollows out the soil of the banks, and the estates where during its floods it goes spreading itself beyond its banks.

K 65 [18] r.

The eddies of water are always produced in the middle water.

The middle water is that above the mouth of the water which is bent across near to where it runs into the canal.

The middle water is that between the water that is falling and that which is thrown back. K 93 [13] v.

Should two streams of water encounter each other and then bend together in the same flight, the middle water will be found beyond this flight upon the current that has less power.

The surface of the water which bends in leaving the straight line of its course for the lateral outlet will be always higher in the centre than at the sides. K 94 [14] r.

Of the water that is poured through a hole of uniform size situated at the bottom of its reservoir, the part that is nearest to the wall of this hole will have greater height and greater movement than the lateral part. K 94 [14] v.

When water is poured in different streams from one reservoir into another that will be higher above its hole which is poured through a hole of less width, and the proportion of the height will be the same as that of the width of the holes. K 94 [15] r.

When two streams of water encounter each other and then pour through the same channel to the bed of a river, eddies are created there on the right hand and on the left, and sometimes these eddies of the right and left become reunited. K 96 [16] r.

The water which moves in a river is either summoned or driven or moves of itself. If it is summoned or as one may say requisitioned what is it that requisitions it? If it is driven what is it that drives it? If it moves of itself this shows it to have a reasoning power; but in bodies which undergo continual change of shape it is impossible that there should be reasoning power, for in these bodies there is no judgment. K 101 [21] v.

RIVERS AND BANKS

All the embankments of rivers against which the waters strike ought to be so much the more slanting as the percussion of the water is of greater power.

Water rises higher upon the bank against which it strikes when it finds this bank more slanting; and consequently descends with greater impetus to strike against the opposite bank. K 102 [22] v.

What difference there is between the percussion of the same quantity of water when it falls through the air or falls shut up in a conduit:

The water which falls in a perpendicular line becomes shrill at some stage of its descent. When it falls through a conduit this is left empty, and here the air fights with the water as will be said in its place. You should not forget however to say that this descent of the water is checked by the condensation of the air in the conduit where the water is. K 103 [23] v.

If the waters that enter into a reservoir or issue forth from it have the holes of exit equal to the holes of entry, and the fall of the entry is longer than that of the exit, the entry will then be greater than the exit until the water of the basin rises, and then they will become equal. K 104 [24] r.

And if the fall of the entry is more beneath the surface than the fall of the exit, although they are of the same size, the entry will be greater than the exit until their powers equalise themselves.

But if in this case the exit covers a longer space of the surface than the entry does then the exit will be greater than the entry.

K 104 [24] v.

What shape will the same quantity of water moving along the same slant have in order that it may be as swift as possible?

Let it have that which will make least contact with the bottom, that is a half-circle.

That water will be swifter when the part that makes eddies through striking upon the bottom and the sides is less in bulk than the rest; and this is the greatest river. K 105 [25] r.

[*Relation of wave and wind*] [*Diagram*]

The wave increases because the wind increases.

D b e f the wind, strikes *e f* the water, and causes it to overflow; *d a e c* the second part of the same wind finds *c e* prepared to overflow, having come from *e f*, and comes behind it with its power; and doubles the power *t v e f* and so makes the wave double. K 106 [26] v.

Whether the percussion made by the water upon its object, is equal in power to the whole mass of the water that strikes when it finds itself in the air, or no.

Which is the easier, to raise the sluice of the mill with the water flowing, up or down or across, or when the water is still.

K 117 [37] r.

Vessels of equal capacity and full of water in double proportion and which empty themselves by holes made in their lowest depth, in each degree of time will change the degrees of proportions in the copiousness of their discharges.

I maintain that if at the commencement of the discharge the water is of double quantity, the amount of the discharge is immediately double in the one case what it is in the other, varying immediately; in such a way that if the descents are divided in six stages in the lesser vessel and twelve in the larger one, when the lesser vessel has had a drop of five stages and the greater five also, this lesser vessel is left with one stage of height of water and the larger with seven, which is in proportion seven times as great. K 128 [48] r.

[*Fall of water*]

Water which falls in the form of a pyramid by a perpendicular line upon a level surface will leap up again to a height and will end its point towards the base of this pyramid, and will then intersect and pass beyond it and fall down. L 1 r.

[*Air replacing water*]

Why the air which fills up the void in a globe from whence the water emerges, enters with the same impetus as that of the water which is poured out. Whatever is resting upon this water turns in contrary movement to that of the water. L 17 v.

[*Rivers*]

The long thing of uniform thickness swells as much in its two opposite sides as it is lowered in its two other opposite sides.

Here the water which is confined in the parallel river increases as much in height as it is lacking in breadth; consequently as it falls it hollows out the place where it has struck.

The parallel rivers may at some part of their length be confined in two ways, namely between their surface and their bed or upon their opposite sides. L 30 r.

[*Falls of water*]

When two streams of water meet at an extremely sharp angle the more powerful hollows out its side of the base most, and makes a sudden depth.

This is the true way of giving the fall while conserving the bank to the water which descends from the said bank. L 31 v.

[*The course of rivers*]

The beds of the rivers uncovered naturally, do not give true indications of the nature and quantity of the objects carried by the waters, because in the deep waters many places are filled with sand, and afterwards in the particular lateral courses of the rivers these deposits of sand are borne above the shingle on which they rested or laid bare beneath, so causing the continual subsidence of the raised bank of this sand which by reason of its lightness accompanies it in its course and is then deposited where the current of the water becomes more tranquil.

The twistings of rivers in flood are such as to burst every dike and all the order that the river keeps when low. L 32 r.

[Falls and courses of water]

Water that has fallen with great impetus from its dam reproduces the twistings of the rivers according to the line of its fall, but when the waters subside, although the line *a b* keeps its place even if this river should swell again, the canal *a b* will become filled with sand, and the volume of the water will follow its natural course. L 32 v.

[Water in percussion]

When water strikes it rises, and it acquires weight in proportion as it leaps out of its common surface; this fallen back upon, the other water strikes it and penetrates as far as its bed, which it consumes perpetually; and such a hollow is formed in the length of the sides of the object struck.

To guard against this a flat surface may be formed round any column which has a firm base and is of such breadth that the water that falls back is compelled to find it. L 33 r.

The less curved the bank where the leap of the river strikes it the farther removed will the second leap be from the spot from which the first departed. L 36 v.

The eddies of rivers are of several kinds; of these some are hollow in the centre after the manner of a concave pyramid; others full in the centre like a raised cone; some throw things up from the bottom, others submerge things borne on the surface of the water; and the one creates a hollow underneath the bank which forms its side, the other fills it up.

These eddies serve the purpose by their revolutions and delays of equalising the excessive speed of the rivers; and as therefore the eddies at the side are not sufficient, by reason of the narrowness of the rivers, it becomes necessary that new kinds of eddies should be created which shall turn the water over from the surface to the bottom and at various different angles; of these some meet at the bottom and churn up all the soil which the eddy of the surface has in course of time deposited. And the other eddies do the same against the banks of the rivers.

B.M. 30 v.

A book of how to drive back armies by the fury of floods caused by the letting loose of waters.

A book of how to inundate armies by closing the outlets of the valleys.

A book to show how the waters bring down in safety logs hewn in the mountains.

A book of how boats are forced against the rush of the rivers.

A book of how to raise great weights by the simple increase of the waters.

A book of how to guard against the rush of rivers so that cities may not be struck by them. B.M. 35 r.

Of the inequality in the hollow of a ship.

Book of the inequality of the curve of the sides of ships.

Book of the inequality in the position of the helm.

Book of the inequality in the keel of ships.

Book of the difference in the holes through which water is poured out.

Book of the water contained in vessels with air and of its movements.

Book of the motion of water through a syphon.

Book of the clashing together and concourse of water proceeding from different directions.

Book of the varying shapes of the banks along which the rivers pass.

Book of the various shoals formed below the locks of the rivers.

Book of the twistings and bendings of the currents of the rivers.

Book of the different places whence the waters of the rivers are derived.

Book of the shapes of the banks of the rivers and their permanence.

Book of the perpendicular fall of water upon various objects.

Book of the course of water when impeded in various positions.

Book of the various shapes of the obstacles which impede the course of the waters.

Book of the hollow or rotundity formed at the bottom round the various obstacles.

Book of how to conduct navigable canals over or beneath the rivers which intersect them.

Book of the soils which drink up the waters of the canals and of the means of protection.

Book of the creation of channels for rivers which quit their bed when it is filled up with soil. B.M. 45 r.

[*Of water*]

This wears away the lofty summits of the mountains. It lays bare and carries away the great rocks. It drives away the sea from its ancient shores for it raises its base with the soil that it carries there. It shatters and devastates the high banks; nor can any stability ever be discerned in these which its nature does not suddenly bring to naught. It seeks out with its rivers every sloping valley where it may carry off or deposit fresh soil. Wherefore many rivers may be said to be those through which all the element has passed, and the sea has gone back many times to the sea, and no part of the earth is so high but that the sea has been at its foundations, and no depth of the ocean is so low but that the loftiest mountains have their bases there. And so it is sometimes sharp and sometimes strong, sometimes acid and sometimes bitter, sometimes sweet and sometimes thick or thin, sometimes it is seen bringing hurt or pestilence, sometimes health-giving, sometimes poisonous. So one would say that it suffers change into as many natures as are the different places through which it passes. And as the mirror changes with the colour of its object so it changes with the nature of the place through which it passes:—health-giving, noisome, laxative, astringent, sulphurous, salt, incarnadined, mournful, raging, angry, red, yellow, green, black, blue, greasy, fat, thin. Sometimes it starts a conflagration, sometimes it extinguishes one; is warm and is cold; carries away or sets down, hollows out or raises up, tears down or establishes, fills up or empties, raises itself up or burrows down, speeds or is still, is the cause at times of life or death, of increase or privation, nourishes at times and at times does the contrary, at times has a tang of salt, at times is without savour, at times submerges the wide valleys with great floods. With time everything changes. B.M. 57 r.

At times it goes twisting to the northern parts, eating away the base of its bank; at times it overthrows the bank opposite on the south; at times it turns towards the centre of the earth consuming the base which supports it; at times leaps up seething and boiling towards the sky; at times revolving in a circle it confounds its course; at times it extends on the western side robbing the husbandmen of their tilth; at times it deposits the soil it has carried away in the eastern parts. And thus at times it digs out, and at times fills in where it has taken away and where it has made a deposit. Thus without any rest it is ever removing and consuming whatever borders upon it. So at times it is turbulent and goes ravening in fury, at times clear and tranquil it meanders playfully with gentle course among the fresh verdure. At times falls from the sky in rain or snow or hail; at times forms great clouds out of fine mist. At times moved of itself, at times by the force of others; at times gives increase to things that are born by its life-giving moisture, at times shows itself either fetid or full of pleasant odours. Without it nothing can exist among us. At times it is bathed in the hot element and dissolving into vapour becomes mingled with the atmosphere, and drawn upwards by the heat it rises until having found the cold region it is pressed closer together by its contrary nature, and the minute particles become attached together. And as when the hand under water squeezes a sponge which is well saturated so that the water shut up in it as it escapes through the crevices is driven into the rest and drives this from its position by its wave, so it is with the cold which the warm moisture compresses, for when it has reduced it to a more solid form the air that is pent up within it breaks by force the weakest part, and hisses just as though it was coming out of bellows when they are pressed down by an insupportable weight. And thus in various positions it drives away the lighter clouds which form obstacles in its course. B.M. 57 v.

... stage of declivity. Water initiates its own movement.

Book of the various ways of levelling waters.

Book of how to divert rivers from places where they do damage.

Book of how to straighten the course of rivers which cover too much ground.

Book of how to divide rivers into many branches and make them fordable.

Book of how waters pass through seas with different movements.

Book of how to deepen the beds of rivers by different currents of water.

Book of how to control rivers so that the small beginnings of the damage they cause may not increase.

Book of the different movements of waters which pass through channels of different forms.

Book of how to prevent the small rivers diverting a larger one as their waters strike it.

Book of how to ascertain the lowest level in the current of the surface of rivers.

Book of the origin of rivers which flow from the lofty summits of the mountains.

Book of the variety of the movements of waters in their rivers.

B.M. 122 r.

[*Why the beds of straight rivers are deeper in the centre than at the sides*]

The current of a straight river is higher in the centre than at the sides, and rises towards the sky with greater waves and turns in greater depth towards the centre of the earth.

And this occurs because the current is the clashing together or intersection of the reflex movement of the waves, which leap back after striking against the bank and running back to the opposite bank clash with the contrary movements, and these resisting each other and neither being able to penetrate into the other leap back high out of the water, and then falling back—having acquired weight while in the air—plunge beneath the water there where they strike it.

B.M. 135 v.

How rivers widen their valleys and wear away the roots of the mountains at their sides:

The bases of the hills as their valleys grow deeper are bent back towards the course of the river, as though they should wish to demand back from the speeding river the soil of which it has despoiled them.

This proceeds from the nineteenth of this treatise which says: the current of the river eats away the base of the mountain on one side where it strikes and gives it back to the opposite side to which it is deflected.

In great valleys the river changes its bed.

The rivers in great valleys make greater changes in their beds in proportion as they are farther away from the roots of the mountains. This is proved by the ninth of this which says: the largest rivers flow through the largest valleys which have been made by them, and by reason of their size they are continually consuming the waves that flow from their banks, carrying them always back to the current of the river.

OF CHANGES IN THE MOUTHS OF RIVERS

The mouths of rivers are continually bending and descending behind the course of their principal stream, and this proceeds from the former [rule] which says: water takes away with its wave from the bank where it strikes and gives back to the opposite bank where it is deflected.

Valleys are continually growing deeper.

Valleys continually grow wider and deeper and rivers continually change their position. B.M. 161 r.

PERCUSSION OF WATER FALLING UPON DIVERS OBJECTS

The water which falls in a perpendicular line through a round pipe upon a level place will make a circumambient wave round the site of its percussion, within the circumference of which the water will move very rapidly and be spread very thinly round about this place which has been struck, and at the end it will strike into the wave produced by it which seeks to return to the place of the percussion.

B.M. 167 v.

Water is that which serves the vital humour of this arid earth.

It is the cause which moves it through its veins contrary to the natural course (desire) of weighty things; it is like that which moves the humours in all kinds of living bodies, and . . .

And as the water is driven up from the lower part of the vine towards its severed stems and afterwards falls back to its roots, penetrates these and rises again anew, so from the lowest depth of the sea the water rises to the tops of the mountains, and falls down through their burst veins and returns to the sea and rises again anew. Thus up and down, in and out, unresting, now with fortuitous, and now with natural motion, now in its liberty and now constrained by its mover, it goes revolving and, after returning in force to its mover, rises again anew and then falls anew; so as one part rises the other descends.

Thus from the lowest depths of the sea the water rises up to the summits of the mountains and falls down low through the burst veins, and at the same time other water is rising: so the whole element ranges about and makes its passage many times through the rivers that fall into the sea.

At one time it becomes changed to the loftiest clouds, and afterwards it is pent up within the deep caverns of the earth.

It has nothing of itself, but moves and takes everything, as is clearly shown when it is distilled.

Thus hither and thither, up and down, it ranges, never resting at all in quietude, always flowing to help wherever the vital humour fails.

Now taking away the soil, now adding to it, here depositing logs there stones here bearing sand there mud, with nothing stable in bed or bank:

Now rushing on with headlong course, now descending in tranquillity, now showing itself with fierce aspect, now appearing bright and calm, now mingling with the air in fine spray, now falling down in tempestuous rain; now changed to snow or storms of hail, now bathing the air with fine rain; so also now turning to ice and now hot; never keeping any stability; now rising aloft in thin cloud, compressing the air where it shuts it in, so that it moves through the other air after the fashion of a sponge squeezed beneath the water, when what is enclosed within it is driven out through the rest of the water.

B.M. 210 r.

The heat that is poured into animated bodies moves the humours which nourish them.

The movement made by this humour is the conservation of itself and the vivification of the body which contains it.

Water is that which serves the vital humour of the arid earth; it is poured within it, and flowing with unceasing vigour through the spreading veins it replenishes all the parts that depend of necessity on this humour.

And it flows from the vast depths of the mighty ocean in the deep wide caverns that lie hid within the bowels of the earth, whence through the spreading veins upwards against its natural course in continual ascent to the high summits of the mountains it returns through the burst veins to the deep.

Water is that which serves the vital humour of the arid earth; and the cause which moves it through the veins is just that which moves the humours in all the different species of animated bodies.

B.M. 234 r.

Water which serves as the vital humour of the arid earth and for this same cause moves through the spreading veins, is poured into it and works within it as does the blood in human bodies.

The same cause moves the water through its spreading veins as that which moves the blood in the human species, and as through the burst veins in the top of a man the blood from below issues forth, so through the burst veins in the summits of the mountains the waters from below are poured out.

Water after having issued forth from the veins of the earth is abandoned by the moving cause which led it there.

Water in falling from the high summits observes in its movement the desire of all the other heavy things. B.M. 234 v.

And that which with the utmost admiration of those who contemplate it raises itself from the lowest depth of the sea to the highest summits of the mountains, and pouring through the broken veins returns to the shallow parts of the sea, and again rises with swiftness and returns in like descent, and thus in course of time its whole element circulates.

So from high to low, so passing in and out, now with natural and now with fortuitous movement it proceeds, together and united. So with continual revolution it goes ranging round, after the manner of the water of the vine, which as it pours through its severed branches and falls back upon its roots rises again through the passages, and falling back returns in a similar revolution.

The water which sees the air through the broken veins of the high summits of the mountains, is suddenly abandoned by the power which led it there; and when the water escapes from the forces which raise it to a height it resumes in liberty its natural course.

In the same way, so does the water that rises from the low roots of the vine to its lofty summit, and falling through the severed branches upon the primal roots mounts anew to the place whence it fell.

B.M. 235 r.

Water is just that which is appointed to serve as the vital humour of this arid earth, and the cause which moves it through its spreading veins, contrary to the natural course of heavy things, is just what moves the humours in all the species of animated bodies.

This it is which to the complete stupefaction of the beholders rises from the lowest depths of the sea to the highest summits of the mountains, and pouring out through the burst veins returns to the depths of the sea and rises again swiftly and again descends as aforesaid. So from the outer parts, to the inner, so turning from the lower to the higher, at times it rises in fortuitous movement, at times rushes down in natural course. So combining these two movements in perpetual revolution it goes ranging through the channels of the earth.

B.M. 236 v.

OF THE WEIGHT OF THE WATER

Either the water has weight or it has not weight. And if it has weight, why does not it bend the leaves borne on the bed where it rests? And if it does not bend them, it does not give its gravity to the bottom of the water. And if it does not give its gravity, what supports it? Its bed supports it, but it does not receive weight, because it is proved that water has no weight except above an element lighter than itself such as air and fire, and other liquids such as oil and the like. And if this is the case, why does a vase in the air weigh more when full of water than when full of air? The water does not weigh on their sides, but the vase when filled has weight in the air, which it would not have under water except to the extent of the weight of the material of which the vase is made. And the sea does the same upon its vase the earth, and the shores uncovered to the air are the lips of the vase that receives it. Which vase, being conjoined to the rest of the earth, throws its weight upon the air of its antipodes in the increase of the sea, because such antipodean seas balance each other in their weights through being opposite; and the inequality produced their weights, and from this caused the sea to be changing its position continually, the centre of gravity of the earth together with the water also changing its position. B.M. 266 v.

[*Drawings*]

Because *n c* is of a width similar to *a o*, and in like manner because *m i* is slightly less, these waters will be almost all at one level.

Forster III 32 v.

The water *a b* will be very considerably higher than the water *d e*.

The water *r m* will be almost equal, and the part *o* of the back-current will be extremely shallow and will hollow out the bed; *p* will be higher by reason of the percussion, *x* lower at the mill . . .

Forster III 33 r.

SIGNS OF HIDDEN DEPTHS OF WATER

When within the smooth water you see a spreading eddy there is a fall and rebound of water. Forster III 40 r.

MOVEMENT OF WATER

Why do the lines of the water pouring into a hole not direct themselves to its centre? Forster III 75 v.

Why do the circles of the water not break when they intersect?

Forster III 76 r.

Why the water is higher in one part of the sea or river than in another, and why in many rapidly moving eddies the water is lower in the centre of the eddies than at the sides.

On the Movements of Liquids by Galen. Quaderni II 16 r.

Water cannot move of itself unless it descends, and if it moves without descending it is moved by something else, and if it moves without being moved by anything else it is a reflex movement and of short life.

Quaderni II 16 v.

On how to bend the course of a river through its valley.

And you who desire to control the course of the river and to be obeyed by it, you only need to cause its current to bend, for where this bends it wears away the bottom and draws after it all the rest of the water of its river. Quaderni IV 2 r.

WHAT IS THE CURRENT OF WATER

The current of water is the concourse of the reflections which rebound from the bank of the river towards its centre, in which concourse the two streams of water thrown back from the opposite banks of the river encounter each other; and these waters as they encounter each other produce the biggest waves of the river, and as these fall back into the water they penetrate it and strike against the bottom as though they were a substance heavier than the rest of the water, and rub against the bottom, ploughing it up and consuming it, and carrying off and transporting with them the material they have dislodged. And therefore the greatest depth of the water of a river is always below the greatest current.

It is possible for water in a brief time to perforate and make a passage through stone. Quaderni IV 2 r.

Watch the movement of the surface of water, how like it is to that of hair, which has two movements, one following the undulation of the surface, the other the lines of the curves: thus water forms whirling eddies, part following the impetus of the chief current, part the rising and falling movement. Windsor: Drawings 12579 r.

The movement of the wave is swifter than the movement of the water that produces it. This is seen by throwing a stone into still water, for it creates around the spot where it strikes a circular movement which is swift, and the water which creates this circular swelling does not move from its position nor do the objects which float on the surface of the water. Leic. 14 v.

[*With drawing of section of river in which are the words 'Arno', 'Rifredi', 'Mugnone'*]

When a lesser river pours its waters into a greater and this greater flows from the opposite bank, the course of the lesser river will be bent by the onset of the greater. And this occurs because when this greater river fills up the whole of its bed with water it comes to form an eddy under the mouth of this river, and thus drives with it the water that has been poured out by the lesser river. When the lesser river pours its waters into the greater river which has its current crossing the mouth of the lesser river, its waters will bend in the direction of the current of the greater river. Leic. 15 r.

DIVISIONS OF THE BOOK

Book 1 of water in itself
Book 2 of the sea
Book 3 of the springs
Book 4 of rivers
Book 5 of the nature of the depths
Book 6 of the objects
Book 7 of different kinds of gravel
Book 8 of the surface of water
Book 9 of the things that move in it
Book 10 of the means of repairing [the banks of] rivers
Book 11 of conduits
Book 12 of canals
Book 13 of machines turned by water
Book 14 of how to make water ascend
Book 15 of the things which are consumed by water. Leic. 15 v.

FROM 'THE ORDER OF THE BOOK OF WATER'

Whether the flow and ebb are caused by the moon or sun, or are the breathing of this machine of the earth. How the flow and ebb differ in different countries and seas.

How in the end the mountains will be levelled by the waters, seeing that they wash away the earth which covers them and uncover their rocks, which begin to crumble and are being continually changed into soil subdued alike by heat and frost. The waters wear away their bases and the mountains bit by bit fall in ruin into the rivers which have worn away their bases, and by reason of this ruin the waters rise in a swirling flood and form great seas.

How in violent tempests the waves throw down every light thing and suck much earth into the sea, which causes the water of the sea to be turbid over a wide space.

How loose stones at the base of wide steep-sided valleys when they have been struck by the waves become rounded bodies, and many things do the same when pushed or sucked into the sea by these waves.

How the waves quiet down and make long stretches of calm water within the sea without any movement when two opposite winds meet together at this spot; thus at these meeting places various shapes made up of calm sea are visible surrounded by the tiny waves of a moderate sea. Leic. 17 v.

PROPOSITIONS

Water of itself does not move unless it descends.

That water will be highest which is farthest removed from the centre of its sphere. And that surface of water is said to be lowest which is nearest to the centre of its sphere.

No surface of water which is contiguous to the air is lower than the surface of its sphere. The waters of the salt seas are fresh at their maximum depth. The waters range with perpetual movement from the lowest depths of the seas to the topmost summits of the mountains, not following the law of heavy things; and in this instance its action resembles that of the blood of animals which is always moving from the sea of the heart and flowing towards the summit of their head; and so when a vein there has burst open, as one sees if a vein bursts in the nose, the whole of the blood from below rises up to the height where the vein has burst.

When the water gushes forth from the burst vein in the earth it follows the law of other things which are heavier than the air and so always seeks the low places.

That water will be swifter which descends by the less slanting line. And that water will be slower which moves along a more slanting line.

The Nile and the other rivers of great size have very many times poured out the whole of the element of water and restored it to the sea. The veins flow with infinite ramifications through the body of the earth. The waters assume as many different natures as the places are different through which they pass. If it were possible to make a well which should pass through the earth on the opposite side and for a river to descend through this well, the head of the river which entered there first would descend through this well and pass the centre of the elements without making any reflex movement, and it would pour as much water on the far side of this centre as it had from the opposite side.

And if, because of some deep valley, the line on the opposite side of the well were shorter than on this side, this water would fill up the valley, however large it was, until it equalled the weight of the water in the well, although in some part the centre (of gravity) of the water and of the earth united together would move somewhat from its first position through the weight of the water, which would be increased on the opposite side of the earth where it was not at first. The centre (of gravity) of the water and earth joined together is moved when the weight of the sea moves because it is carried by the winds.

Leic. 21 v.

THIRTY-NINE CASES

How the bottoms of rivers and ditches become trampled by big animals and this causes the muddy waters to escape and they thus leave in their course the soil in which they were loitering. How in the manner described above canals may be constructed through level lands. How to convey away the soil from canals which have become choked up with mud by the opening of certain sluices which are moved upwards by the canal.

How one ought to straighten rivers. How one ought so to provide that rivers do not sweep away other men's possessions. How one ought to maintain the beds of rivers. How one ought to maintain the banks. How the banks when broken should be repaired. How one ought to regulate the impetus of rivers in order to strike terror into the enemy so that he may not enter the valleys of this river to damage them.

How the river in order to be crossed by your army ought to be converted into many small branches. How one ought to ford rivers below the rows of horses so that they may protect the infantry from the rush of the water.

How by the use of wine-skins an army is able to cross a river by swimming. How the shores of all the seas that touch one another are of equal height, and are the lowest part of the land which meets the air. Of the manner of swimming of fishes; of the way in which they leap out of the water as may be seen with dolphins, for it seems a marvellous thing to make a leap upon something which does not stand firm but slips away.

Of the manner of swimming of animals of long shape such as eels and the like. Of the way of swimming against the currents and great falls of rivers. Of the way in which fishes swim when they are round in shape. How animals which do not have the hoof cleft asunder are not able to swim. How all the other animals which have feet with toes are by nature able to swim, except man. In what way a man ought to learn to swim. Of the way in which a man should rest upon the water. How a man ought to defend himself against the whirlpools or eddies of the waters which suck him down to the bottom. How a man when sucked down to the bottom has to seek the reflex current which will cast him out of the depths. How he ought to propel himself with his arms. How he ought to swim on his back.

How he can only remain under water for such time as he can hold his breath.

How by an appliance many are able to remain for some time under water. How and why I do not describe my method of remaining under water for as long a time as I can remain without food; and this I do not publish or divulge on account of the evil nature of men who would practice assassinations at the bottom of the seas by breaking the ships in their lowest parts and sinking them together with the crews who are in them; and although I will furnish particulars of others they are such as are not dangerous, for above the surface of the water emerges the mouth of the tube by which they draw in breath, supported upon wine-skins or pieces of cork.

How the waves of the seas continually consume their promontories and rocks. How the shores of the seas grow continually towards the centre of the sea. The reason why the gulfs of the seas are created. The cause why the gulfs become filled up with earth or seaweed.

The cause why round about the shores of the seas there is found a large high bank called the mound of the sea.

Why the waves are higher when they touch the bottom nearer to the shore than they are on the high sea.

How at the mouths of certain valleys the gusts of wind strike down upon the waters and scoop them out in a great hollow, and carry the water up into the air in the shape of a column and of the colour of cloud.

And this same thing I once saw taking place on a sand-bank in the Arno, where the sand was hollowed out to a depth of more than a man's stature, and the gravel of it was removed and whirled a great distance apart, and assumed in the air the form of a mighty campanile; and the summit of it grew like the branches of a great pine, and then it bent on meeting the swift wind which passed over the mountains.

How the wave is least towards the approaching wind because the bank serves it as a shield.

How the water that finds itself between the percussions of the waves of the sea becomes changed into mist.

Of eddies wide at the mouth and narrow at the base.

Of eddies very wide at the base and narrow above.

Of eddies of the shape of a column.

Of eddies formed between two masses of water that rub together.

Leic. 22 v.

How waves do not penetrate one another but leap back from the place where they have struck; and every reflex movement flies away at equal angles from the striking place.

The reflex movement of water within water will always be of the same shape as its falling movement. By this reflex movement I do not mean that which springs back within the air but that which follows along its surface.

As the wave of the sand moves considerably more slowly than the wave of the water that produces it, so the wave of the water created by the wind is much slower than the wave of the wind that produces it, that is the wave of the air. The wave of the air performs the same function within the element of fire as does the wave of the water within the air, or the wave of the sand, that is earth, within the water; and their movements are in the same proportion one to another as is that of the motive powers within them.

The more powerful current will cleave asunder the less powerful and pass through the middle of it. Currents of equal power which clash together leap back from the site of their percussion. A whole mass of water in its breadth, depth and height is full of innumerable varieties of movements, as is shown on the surface of water of a moderate degree of turbulence, in which one sees continually gurglings and vortices, with various eddies formed of the more turbid water from the bottom that rises to the surface. How every seven years the waters of the Adige rise and then fall, and it makes a famine as it rises. Leic. 23 r.

How water has tenacity in itself and cohesion between its particles. This is seen from the fact that a drop before separating itself from the remainder stretches itself out as far as it can, and offers resistance in its union until it is conquered by the excessive weight of the water which is continually increasing upon it. How water serves as a magnet for other water. This is seen in the process of a drop becoming detached from the remainder, this remainder being stretched out as far as it can through the weight of the drop which is extending it; and after the drop has been severed from this mass the mass returns upwards with a movement contrary to the nature of heavy things. It may be seen how the larger drop of water instantly takes up into itself the smaller drops which come into contact with it; and the minute particles of moisture diffused through the air act in the same way, for they become compressed, making themselves a magnet one for another until at last their weight so increases as to conquer the resistance of the air that first sustained them, and so they descend in the form of rain.

It may be shown with a bubble of water how this water is of such uniform fineness that it clothes an almost spherical body formed out of air somewhat thicker than the other; and reason shows us this because as it breaks it makes a certain amount of noise. Leic. 23 v.

It is possible to devise obstructions which will preserve the embankment against the friction of the current.

You should therefore cause blocks of coarse shingles to be constructed ten braccia apart; and let them be ten braccia wide with height varying according to the height of the embankment and of a thickness of three braccia. And they should be set to slant in the direction from which the water comes; and each of itself will serve as a shield to the water and throw it back towards the centre of the stream.

When the obstruction covered by the water slants very considerably in the direction from which the water comes, the stroke of the water will only cause a small hollow in front of this obstruction and it will deposit a considerable quantity of soil behind it.

If the obstruction is entirely upright and the water flows over it it will form a deep hollow in front of it and will only deposit a small amount of soil behind it. And if the obstruction has a lesser obstruction in front of it which leans against it there will be no hollow in front of this lesser obstruction for so far as its bulk extends. If the obstruction have another near behind it the hill of sand will be suddenly cut and dug out in a new hollow.

How the rivers, in their great floods, fill up all their greatest depths with sand or stones, except the places where the river is confined, as when it passes through the arches of bridges or other constricted places; and it does this because behind these arches it strikes against the front of their columns, and rises in a swirling flood, and raises itself, and so with fury makes up for the delay that has taken place before the said bridge or other object. Leic. 24 r.

If the obstructions of the waters are permanent the deep places of the rivers caused by them will also be permanent. And if the obstruction of these waters is movable the deep places caused by it will also be movable. And if the movable obstruction is near the bank of the river it immediately will become the cause of bending the whole river; and this is due to the fact that the water which passes between the obstruction and the bank hollows out this bank. And even though the obstruction proceed upon the bed of the river behind the current of the waters, it does not follow that the concavity already made in the bank will not proceed continually to grow and increase because of the water that ranges within it, as is shown by the fourth of the third; and that the water which leaps back from it to the opposite bank will not create another similar concavity in this bank; and this will then proceed continuously to increase, and then it returns leaping back beneath the first concavity; and so it proceeds time after time until this impetus is consumed amid the universal current of the river.

Leic. 24 v.

TWELVE CASES

These are the cases that have to stand in the beginning:

The air which is submerged together with the water which has struck upon the other water returns to the air, penetrating the water in sinuous movement, changing its substance into a great number of forms. And this occurs because the light thing cannot remain under the heavy, rather is it continually pressed by the part of the liquid which rests upon it; and because the water that stands there perpendicular is more powerful than the other in its descent, this water is always driven away by the part of the water that forms its coverings, and so moves continually sideways where it is less heavy and in consequence offers less resistance, according to the fifth of the second. And because this has to make its movement by the shortest way it never spreads itself out from its path except to the extent to which it avoids that water which covers it above.

When the air enclosed within the water has arrived at its surface it immediately forms the figure of a half-sphere, and this is clothed with an extremely thin film of water. This occurs of necessity because water has always cohesion in itself, and this is the more potent as the water is more sticky; and this air having reached the opening of the surface of the water and not finding there any further weight to press upon it, raises its head through the surface of the water with as great a weight of water joined to it as the aforesaid tenacity can have; and it stops there in a perfect circle as the base of a half sphere, which has the aforesaid perfection because its surface has been uniformly expanded by the uniform power of the air. And it cannot be more than a half-sphere because spherical bodies attain their greatest width at their diameter; and if this air that is enclosed were more than a half-sphere the base would be less than where the diametral line is, and consequently the arc of this half-sphere would not have shoulders or real resistance in its weakest, that is its widest part, and therefore it would come about that it would break in this spot of its greatest width, because the weakest part of any arc is always the end of its greatest width.

The air emerges with impetus in spherical form clothed with an extremely thin film of water, away from the body of the water; and this air by reason of the weight that it has acquired cannot pour itself into the other air, but held back by the adhesiveness of the water with which this film was formed falls down again by its excess of weight, continually growing in circumference, because the amount of the air which at first was in the whole of the aforesaid spherical body is afterwards reduced by half, and this is of itself capable of containing all this air, so that this spherical body goes on descending so far towards the surface of the water that it unites with it, finding there as I have said before greater width than in its own diametral line.

Nor has the air clothed with a thin film of water perfect sphericity in the aforesaid instance, because the part of the water with which this air is clothed, is heavier where it is more perpendicular to the centre of the circle, which makes itself the base of this half-sphere, and therefore in this position it lowers itself more; because that part of a thing supported in its extremities is so much weaker as it is more distant from its foundation, and that thing descends more rapidly which has the weaker support. That part of the air clothed by a film of water will be of most perfect sphericity which is least in size; this is proved by the reason stated above, because these bodies are clothed with films of equal thickness: for if the air that escaped from the surface of the water was small in amount it raised up a small quantity of this film, and clothed itself in it; and since its lesser[1] altitude is nearer its foundation than was that of a greater, it maintains itself more than this greater. The air which is subdued by the weight of the film of water which clothes it penetrates in minute particles through this film, and these, for the reason stated, cannot be separated from their state of connection or adhesion to it, and therefore through the weight it has thus acquired it descends from the sides of this body, and remains

[1] MS. has *maggiore*.

joined to the base of the middle sphere of air from whence it descended.

It breaks the middle sphere of the air clothed by the water in the third part of its curve; this is proved with the arches of walls, and therefore I will not treat of it in these notes, but I will place it in the book where it is necessary.

That part of the water is higher which is more remote from the centre of the sphere of fire and of the air and of the water, but not of the earth, because this has not a mathematical spherical shape; and for this reason the centre of its gravity is not concentric with the centre of the spheres of the other three elements.

The water of itself does not move unless it descends: therefore, when it is in its sphere it does not have one part of itself lower than another, and therefore of itself it will not move unless it is moved by others: and the two aforesaid proofs are sufficient to prove that water is spherical and of itself without movement; and as a consequence all the waters that move of themselves are lower at one extremity than at the other, that is in their surface; so finding the descent it runs there because there is no support for it there.

How the air can never of itself remain beneath the water but always wishes to be above in its contact: in proof of this let it be supposed that there are three elements and that the earth is nothing and that one allows a quantity of water to fall through the air; this cannot stay above the air, because the weaker liquid body cannot support the heavier, and consequently the air since it is a body thinner than the water and therefore is not able to support it will give it place; and this it will continue to do until the water has reached its lowest depth, that is assuming that it has not become evaporated or changed into air through its long friction with the air; but let us suppose that so much turns that a part arrives there: I say that after consuming its impetus between the reflex and falling movements which it would make around its centre it would come to a stop at this centre under all the sphere of air equally, because the centre of the elements is the lowest part that can be found in them, since the lowest is that part which is farthest removed from the greatest height of its whole. This is the conception.

Water attracts other water to itself when it touches it: this is proved from the bubble formed by a reed with water and soap, because the hole, through which the air enters there into the body and enlarges it, immediately closes when the bubble is separated from the reed, running one of the sides of its lip against its opposite side, and joins itself with it and makes it firm.

Also a small drop enters into the body of the other water. If you should grant me by the proof of these bubbles of water that water has tenacity though it be small and thin, you grant me that that which makes the part will make its whole.

The bubble formed within the air by a reed, through which it is blown, does not fall in spherical shape, when it becomes detached because its excess of water runs below and makes it heavier there than elsewhere, and consequently the movement there is hurried, and breaks it above at a third. Leic. 25 r.

Every current has three central lines, which are situated in the middle of its greatest power: of these one is at the contact made by the water with the bed that receives it; the second is at the middle of its depth and width; the third is formed on the surface; but that of the middle is the principal one for it guides the whole course and divides all the reflex movements and turns them to their appointed directions. The higher central line of the current of the water is the upper line of the falling movement, and the lower of the reflex whirling movement, that is that which turns itself over and falls down upon the falling movement upon which it takes its leap; but let us leave the revolutions of the waters and their changes from below upwards as far as concerns these definitions, and speak only of the water remaining on the surface, that is as far as concerns its central lines. The central line of the surface of the current is always in the most prominent part of the water which surrounds the object struck by it; and the central line is only that which after striking upon a smooth-faced object falls back upon itself. The central line of the bottom of the current after striking upon the smooth object, is turned over towards the centre of the earth, and rambles about so much in scraping the bed that it makes a hollow large enough to contain its revolutions; and all the other lateral lines slope to the bed and hollow it. [To consider] whether the wave of the water causes the formation of the wave of sand above its bed or whether the wave of the bed is the cause of the wave on the surface of the water. [To consider the] difference between the waves, from knowing their depth: which may always be discovered between the falling and the reflex movement of the waters. [To consider] how the least depth within the banks of any expanse of water will be found at the end of its reflex movement. How also the least depths of rivers will be found at the sides of the currents where they unite with other currents. [To consider] how in between two currents there are always shallows. The highest part of the surface of the water that strikes the object will strike it in its centre if it be of smooth front or pointed with sides of equal slant and length. But unless the angle is in the middle of the front of the object the highest elevation of the wave that strikes it will no longer be in the centre of this front but opposite to the aforesaid angle. The water of the surface that is moved in tiny ripples by the wind, always moves so much more swiftly than the wave of the water, in proportion as the wave is swifter than the natural movement of the water, and as the natural movement of the water is swifter than the wave of the sand, and as the wave of the sand is swifter than the wave of the earth that forms the river bank. But I ought first to say that the movement of the free air is so much swifter than the movement of the air that strikes the water, because that part of the wind that strikes the water is checked by the resistance of the surface of the water. All the waves of the sand which travel with the water are as much slower than the waves of the sand that travel with the wind as the movement of the water is slower than the movement of the wind. Leic. 25 v.

In these eight sheets there are seven hundred and thirty conclusions as to water.

When the wave has been driven on to the shore by the force of the wind it forms a mound by putting its upper part at the bottom, and turns back on this until it reaches the spot where it is beaten back anew by the succeeding wave which comes below it and turns it over on its back, and so overthrows the mound and beats it back again on the shore mentioned before; and so continues time after time; turning now to the shore with its upper movement and now with its lower fleeing away from it.

How it is not possible to describe the process of the movement of water unless one first defines what gravity is and how it is created or dies.

As the wave after striking on the sea shore turns back along the bed of the sea behind its mound, it encounters the following wave which comes from the high sea, and breaks itself upon it and divides itself; part leaping towards the sky and then falling down and turning back, part towards the bed of the sea; and this continues towards the sea, carrying with it the lower part of the water that struck upon it. Were it not for it doing thus the seaweed and the wrack of the tempests would not be able to be carried from one shore and deposited upon another. If the water of the sea turns towards the sea above its bed after the percussion made upon its shore, how can it carry with it the shells, molluscs, 'buovoli', snails and other similar things produced in the bed of the sea, and throw them upon this shore? This movement of the aforesaid things towards the shore commences when the percussion of the falling wave divides the reflex wave into the aforesaid two parts, for the things raised from the bottom often leap up in the wave that returns to the shore, and being solid bodies are driven towards the mound, which then draws them back with it towards the sea; and so continues in succession until the storm begins to abate, and stage by stage it leaves them where the greater wave reaches, that is that as the succeeding wave does not return to the same mark where it had deposited the booty that it carried, this booty remains where it has been left by the wave; and this process continues as the waves grow less. There remain the things cast up by the sea within the space that lies between the first mound of the wave upon the shore and the mound made by the wave that comes from the deep sea. If the whole sea rests and supports itself upon its bed the part of the sea rests upon the part of the bed: and as water possesses gravity when out of its element it ought to weigh down and press upon the things that rest on its bed. But we see the contrary, for there the seaweed and grass that grows in these depths are not bent or crushed upon the bottom but cleave it directly as though they were growing within the air.

So we arrive at the conclusion that all the elements, though they are without weight in their own sphere, possess weight away from their sphere, that is away towards the sky, but not away towards the centre of the earth; because if it proceeds away towards this centre it finds an element heavier than itself, with its thinnest and lightest part touching an element lighter than itself, and the heavier part of the element is so placed as to be near the element that is heavier than itself.

How water when transformed becomes changed into wind which is so much drier as the process of transformation is more complete.

How wind is generated by the coagulation of the water within the air, for the air hastens to where there is a lack of it, and so it flees from where it is in excess. How the air has a greater volume where there is more wind, because the air there is thicker.

How the winds are strongest in the moist seasons, and more so in the rains than in clear weather. How great winds proceed from the mountains that are covered with snow; and to this the sailors bear witness for they experience it every day. And this is brought about through the fact of the snow becoming dissolved in the air, and being dissolved in very fine particles; hence philosophers say that there are dry land vapours; as to which I have nothing to say.

How the wind, proceeding from the cloud, is not exhaled in a circle through every line away from the cloud, because it acquires more weight than the air through which it passes, and so of necessity is bent to the ground as are all the things that are heavier than the air, and it rambles through it, driven by that which follows, which is created behind it, or by the impetus it has acquired from its past movement.

Leic. 26 v.

That water may have tenacity and cohesion together is quite clearly shown in small quantities of water, where the drop, in the process of separating itself from the rest, before it falls becomes as elongated as possible, until the weight of the drop renders the tenacity by which it is suspended so thin that this tenacity, overcome by the excessive weight, suddenly yields and breaks and becomes separated from the aforesaid drop, and returns upwards contrary to the natural course of its gravity, nor does it move from there any more until it is again driven down by the weight which has been reformed. From this proposition two conclusions follow, of which the first is that the drop has cohesion and nerve-structure in common with the water with which it is joined; secondly that the water drawn by force breaks its cohesion, and the part that extends to the break is drawn up by the remainder in the same manner as is the iron by the magnet. The same is seen with water passing through a filter, for the greater weight of the water that is outside the vessel draws back the lesser weight of the water which this filter holds back curved within the vessel.

One may offer a proof of the tenacity of water and set it out in proportion, thus:—if a drop of water of two grains is supported by water of the volume of half a drop by how much will a pound be supported? And in this way we shall arrive near the truth. The sand weighs more than the water; and if there be left within the air in continuous line a quantity of sand and a quantity of water, separated from the sand but of the same weight as the sand, without doubt the movement of the sand will be slower than that of the water; and this comes about because the lower part of the water draws down the water that is joined to it above, and consequently it makes itself all one body and weighs all together upon the air, which opens below to give it place. This does not happen however with the sand, for in itself it is all separated and loose, and the whole of the amount falls with the same speed that one of its grains would, as they are all equal. So that we may conclude that the continuous descent of the water as it falls through the air proceeds with the speed that its weight requires, because it is a united and continuous quantity; and the sand of the same weight which descends from the same position of the water only proceeds with as much speed as is required by the weight of one of its medium-sized grains, for those that are larger descend more swiftly than those of medium size, and the less descend more slowly.

For if water has in itself adhesiveness and a tendency to unite, the water that is poured from a siphon, being surrounded by air, does not draw itself after that of the siphon; and experience shows us that unless the outlet of the water of the siphon is lower than its entrance into the pipe, the water that continues below its outlet from the pipe will never draw itself after that of the vessel. If in the descent of the water within the air the water above, which drives it downwards, does not descend there with the same speed or a greater, that below will divide itself from that above, if it is swifter.

How the water that descends through the air breaks because the air through which it passes divides it. How the water which is divided as it descends continuously through the air has a medium of spray, which extends from one divided part to the other, and binds them up together. How all the volume of the water which descends through the air in continuous quantities, is constrained to descend with equal movement, because where it made itself swifter it would separate itself from the part that was slower, and where it made itself slower it would be doubled and multiplied by the part that was swifter. How as great a weight of water is displaced as the weight of the thing that is supported by this water. How in the same slant, the water will make itself so much slower in its movement as it is lower upon its bed. How water made to gyrate in swift movement in a vessel by the hands of him who is whirling it round becomes extremely concave at the centre.

Of the great difference there is when water is whirled in a vessel, according to whether the hand is held near to the centre of this vessel or near the larger circle of the surface of the water. How the hand drawn frequently across the vessel up and down produces strange movements and surfaces of different heights. What water does when made to gyrate in an oval vessel. What water does when made to gyrate in a vessel with corners. What water does in a vessel that is struck from below. What water does in a vessel that is struck at the side. What water does in a vessel when the spot is struck on which it is standing.

Of the music of water falling into its vessel. Leic. 27 r.

How nothing evaporates except by means of moisture, which after having been evaporated preserves in itself the nature of the body in which it was infused. How the rumbling produced by the earthquake in the body of the earth proceeds from the destruction of places, torn open by force by the winds which continually strike upon the beds of their great caverns or lakes, covered and shut in within the earth.

But the tempest of the sea, snatched from its shores and borne far over the sea will be turned back, and especially if there is great depth there; and this happens because during a storm the wave of the sea does not penetrate to its great depths; and if it should chance to reach there it changes its movement. The water of the sea during a storm makes a great movement on its bed in a different direction from that of its surface.

The dams of rivers if not of too great width may be made in this manner: a stake such as pile-drivers use should be fixed every three braccia, as big as possible and the bigger the better; and their tops should be of uniform height. On these a log of the shape of a beam should be fastened very firmly; next long trunks with all their branches should be taken and laid upon the aforesaid beam, and they should be fastened to it by using one of the branches as a hook; and this process should be repeated as often as possible, placing the branches towards the coming of the water; and they should then be loaded with shingle and stones; and after the first flood it is left grounded. But remember to fix the branches so that they are raised up and make them fall with the others. And if the river should be narrow you set the beam across from one bank to the other and fix it well; and set the aforesaid branches to lean upon it fastened with their natural hooks. The beam here is only for the purpose of holding the heads of the logs so that they do not drop down; and the branches which stand against the course of the river laden with stones, are not allowed to push this beam or bend its direction because it is held by their natural hooks, and their buried branches do not allow them to move or to tear away the said hooks.

How the diverting of rivers ought to be carried on when the water has completely lost the fury of its current, that is when it shows itself tired. How with a small dam a river may be diverted by aiding and increasing the line where it shows that it wishes to turn of itself.

How a river may be diverted by a few stones if one understands the line of its current; and this movement may be made in the aforesaid line of the water. How the dams of the river should never be formed by placing stakes in deep places but in the more shallow places. How the dams of the rivers when formed of masonry ought to be constructed in the deepest parts of the rivers, so that they may be less in the power of the water which undermines them. How the dams of the rivers ought to be made in the fields away from the rivers and then the said river be directed against them. How the bridges ought also to be made in the fields in that part where it is afterwards intended to direct the river. Leic. 27 v.

The ramifications of the springs of water are all joined together in this earth, as are those of the blood in other animals; and they are in continual revolution, and thus vivified they are perpetually wearing away the places in which they move, both those within the earth and those on the surface of it; and the rivers universally pour out much more water now than formerly: for which reason the surface of the sea is somewhat lowered towards the centre of the world as it has had to fill up the vacuum caused by this increase in these springs; of which I shall speak presently. The heat of the fire generated within the body of the earth warms the waters which are pent up within it in the great caverns and other hollow places; and this heat causes these waters to boil and pass into vapour and raise themselves up to the roofs of the said caverns, and penetrate through the crevices in the mountains up to their greatest height, where coming upon the cold it is suddenly changed into water, as one sees happen in a retort, and goes falling down again and forming the beginnings of rivers which are afterwards seen descending from them. But when the great frosts drive back the heat towards the centre of the world, this heat becomes more powerful and causes a greater vaporisation of the aforesaid water; and this vapour heating the caverns round which it moves in circles cannot form itself into water as it usually does: as is seen in the making of aqua vitæ, for unless the vapour of the wine passed through fresh water it would not change into aqua vitæ, but would go back and become at last so much condensed as to break down every obstacle. We may say the same of water heated in the bowels of the earth, which not finding in its passage places of such freshness as harmonises with it, does not form itself into water as formerly, but condenses and hardens like fire multiplied and condensed within a mortar, which becomes harder and more powerful than the substance that contains it, and so unless it be suddenly dissolved in smoke it instantly hurls itself forward, breaking and destroying whatever opposes its growth. It is the same with the aforesaid steam from the water, for it bursts forth within the bowels of the earth in divers places; ranging about and roaring with great tumult until it reaches the surface; and with a mighty earthquake makes whole regions tremble, and often makes mountains fall in ruin, and lays waste cities and lands in divers parts, and with a mighty hurricane bursts its way forth through the cracks in the earth which it has made; and so by thus escaping it consumes its own might. The wind is formed by the water in the air through the processes of the dissolving and the formation of clouds; that is that when the cloud is dissolved it becomes changed into air and increases in its bulk fitfully and irregularly, since the process of its dissolution does not work uniformly; because the cloud is in itself of varying thinness and density, consequently the part that is thinnest is dissolved most rapidly, and the thick part offers most resistance to this process: this therefore is the cause why the movement of this wind does not proceed uniformly.

And when the cloud is created it also generates wind, since every movement is created from excess or scarcity; therefore in the creation of the cloud it attracts to itself the surrounding air, and so becomes condensed, because the damp air was drawn from the warm into the cold region which lies above the clouds; consequently as it has to make water from air which was at first swollen by it, it is necessary for a great quantity of air to rush together in order to create the cloud; and since it cannot make a vacuum, the air rushes in to fill up with itself the space that has been left by the [former] air, which was first condensed and then transformed into a dense cloud. In this circumstance the wind rushes through the air, and does not touch the earth, except on the summits of the high mountains; it cannot draw the air from the earth, because there would then be a vacuum between the earth and the cloud; and it draws but little air through the traverse and draws it more abundantly through every line. I have already had an opportunity of observing this process; and on one occasion above Milan, over in the direction of Lake Maggiore, I saw a cloud shaped like a huge mountain, made up of banks of fire, because the rays of the sun which was then setting red on the horizon had dyed it with their colour.

This great cloud drew to itself all the little clouds which were round about it. And the great cloud remained stationary, and it retained the light of the sun on its apex for an hour and a half after sunset, so enormous was its size. And about two hours after night had fallen there arose a stupendous storm of wind.

And this, as it became closed up, caused the air which was pent up within it, being compressed by the condensation of the cloud, to burst through and escape by the weakest part, rushing through the air with incessant tumult, acting in the same way as a sponge when squeezed by the hand underneath the water, for the water with which it is soaked escapes between the fingers of the hand that squeezes it, and rushes swiftly through the other water. So it is with the cloud, driven back and compressed by the cold that clothes it round, driving away the air with its own impetus, and striking it through the other air, until the heat that is mingled with the moisture of the cloud that has drawn it to so great a height flies back towards the centre of the cloud, escaping the cold which is its contrary, and having approached towards the centre becomes powerful, and consequently takes fire and makes a sudden emission of damp steam, which surrounds it and creates a furious wind that moves with the fire thrown out by the increasing pressure of the steam; and thus fire is expelled from the cloud as is the flame from the mortar, by the wind increasing behind it; and so this flame compressed by the cloud issues forth, and spreads through the air, with the more radiance in proportion as the fire of which it is formed is more concentrated and of greater heat: and this is the thunderbolt which afterwards ruins and smashes in pieces whatever opposes its destined course.

I have already seen fire created under the water with the movement of a wheel which whirled its arms; and it will do the same at any depth however great.

If the river be turned at the upheaval of the earthquake, it will no longer run forwards but will return into the body of the earth, as does the river Euphrates; and let this serve for any of those at Bologna who lament over their rivers. Leic. 28 r.

That water will rise higher with its wave than the common surface of the water of the lake, when it is nearer the spot at which it falls into the lake. When the waters from different parts meet together in a hole that is in the bed of the river this water will be bored through as far as the entrance of the hole, and the cavity so made will be filled with air as far as the bed of the water.

The revolving movement cannot be continued strictly below the water unless this revolving mass of water has air in the middle of it. That water will form a sudden hollow in its bank of earth which strikes within equal angles at any object that projects from this bank. The rain that parts from the cloud does not all fall on the earth: this is due to its friction with the air that it penetrates, because in the course of this friction it becomes consumed either altogether or in great part and pours itself into the above-mentioned air; and often one sees the clouds descend towards the earth and immediately become cut short in the manner of a horse's tail and remain invisible; and they are changed into wind. Leic. 28 v.

Where the straight course of the water is impeded, there sudden depth will be produced. This occurs because when the course of the water is impeded it is making percussion against an obstacle that impedes it, and because no movable thing can immediately end and consume its impetus, but it must be retained by the body which it penetrates; and also it does not end in this immediately after the percussion, seeing that every percussion is made upon the surfaces of the bodies which are struck; therefore, the penetration of movable things within their objects is a consequence born after their percussion, in which the impetus of the movement is consumed.

The penetration of the movable things within their objects will be of as much less length than their reflex movement made in the same space of the falling movement, as the thing penetrated is thicker than the medium, where this reflex movement is made. Now the water when its straight movement is impeded strikes the object that impedes it, and immediately, not being able to penetrate it, is reflected at almost equal angles; after which percussion it divides and escapes by different lines from the spot where it struck; of these that which raises itself in the air acquires weight, and falls back and penetrates the other water as a heavy thing; after which it strikes and consumes the bed of the river; but in the process of penetration it is struck by the water which flows beneath its surface, and from stage to stage is driven back in threefold movement towards the place where it first struck.

There are three positions of the movement that the water makes on being reflected from its percussion within the water penetrated by it: the first movement is towards the bed of the water; the second is towards the place where the water is moving; the third is whirling movement after the manner of a screw, boring continually the bank and the bed on which it rubs, and always gathering fresh force from the water that follows in succession, thrown back from the bank, which descends upon it from the air, and resubmerges it anew with itself at the bottom.

Here then is a percussion, and the movable thing after having struck the object remains in the position where it was when it made the percussion; and the object struck follows the same line and extent of the course of which the striker was deprived. This happens because in this instance the weights are equal in size, weight and substance, and to the weight of the movable thing has been joined the power of the impetus of which the object was deprived, and it only rested with its natural weight; this is so, because no impetus is consumed immediately, and because the body that strikes is accustomed to make the reflex movement when it finds an object that offers resistance; but here reflex movement is not produced, because the object immediately flies away, bearing with it the power and impetus of its striker; and because always the movable thing, which does not attach itself to its object, is accustomed to finish the remainder of its destined movement in the reflex movement, which starts immediately it has finished its percussion. Here they do not become fixed, because they are of spherical body and of equal substance. It does not advance farther because it has exhausted its impetus in its percussion, and has given it to the object struck; it does not spring back, for it has nothing to serve as a foundation for its spring, after the manner of a man who wishes to jump from a board which is placed on the pavement on top of several pieces of a beam which has been sawn up; for as he gathers impetus for the leap, this impetus communicates itself to and unites with the board which flies away as though upon wheels; and he who would fain leap deprived of the impetus of the leap, is left in the same position in which he was when he formed the intention of leaping; so that from this we may conclude that the impetus can be immediately separated from the body where it was created and pour itself into the object which it has struck.

But if the body struck be lighter than its striker, the length of the movement destined for this striker will be as much shorter as the impetus which is divided from it, attaching itself to the body struck, is diminished. That is, if the body struck was a pound and the striker two pounds, I affirm that the percussion will take away half the impetus and the movement of its striker, and the body struck having only half the power of impetus will take a medium course, but so much more than that made by the striker which follows it as it is lighter than it, and there is less resistance of air; excepting the power of the resistance of the air which is measured by drawing the same movable thing with double power; and if the movements are not of double length, that which is lacking has been taken away from them by the resistance of the air, which may be said to resist in the same proportion as the aforesaid movable thing is lacking in movement when driven by double the power there was at first. And if the object struck was much lighter than the striker, the air will offer much resistance to the movement of the body struck. And if the body struck is double the body that strikes it, its movement will be in the subduplicate ratio of the reflex movement of its striker. And if the bodies which strike are equal and similar and of equal movement and power, then their reflex movements will be equal in length and power. But if the movement of similar and equal bodies be unequal then their reflex movement will be unequal. Leic. 29 r.

OF THE VORTICES OR EDDIES WHICH THE AIR MAKES IN WATER

It often happens that when one wind meets another at an obtuse angle, these same winds circle round together and twine themselves together into the shape of a huge column, and becoming thus condensed the air acquires weight. I once saw such a hollow column assume the shape of a man above the sand of the sea shore, where these winds were ranging round together and digging stones of a considerable size from this hollow, and carrying sand and seaweed through the air for the space of a mile and dropping them in the water, whirling them round and transforming them to a dense column which formed dark thick clouds at its upper extremity; and beyond the summits of the mountains these clouds were scattered and followed the direct course of the wind when it was no longer impeded by the mountains.

[*Of the movement of water*]

That thing is lower which is nearer to the centre of the earth; therefore that will be higher which is more remote from this centre.

Every quantity of water will move towards its lower extremity; and where these extremities are of equal height, this water will not in itself have any movement.

Here it is proved by these two propositions that the waters of the seas which are contingent will never of themselves have movement; and how of necessity they are of spherical surface.

Therefore water that moves of itself has one of its extremities lower than the others; and that which does not move is of the same height in its extremities.

A corollary follows which says that water does not move of itself unless it descends. Leic. 30 v.

The variety of the positions and rates of speed of the waters within their rivers is caused by the variety of the slant of their bed. The variety of the slant of the beds of rivers is caused by the variety of the swiftness of the current of the waters.

Water of itself does not move unless the slant of the bed draws it to itself: what therefore was the cause of this slant of the bed different from its first general slant? For I allow myself to understand that the movements more or less of the waters in the rivers were caused only by the greater and less slants of the beds, as I have set forth above.

And if the first bed of the river was formed with uniform width, slant and straightness, what was the cause of the varying of such conditions as regards the bed? For it is here shown that the water which moves above them must of necessity be of uniform current. The matter which makes the water of the rivers turbid is that which after being carried some distance settles upon their beds, and raises them, and changes the slant of the bed; and in this way it causes the variation in the courses of the waters. And from this we conclude that the water is the cause of the variation of its bed, and that the bed then of necessity changes the courses of the waters in greater or less speed; which variety of courses is then the most powerful cause of varying all the bed of its river; and so it is concluded:—The bed of the rivers is varied by the matter that the course of the water deposits there;

and the variety in the course of the waters is further varied by the irregularity in the bed of the river.

A drop of water that falls in a place of uniform density and smoothness will splash in such a way that the edges of its mark will be at an equal distance from its circumference; and so conversely if it should not fall in a level place. Leic. 33 r.

The centres of the sphericity of water are two: the one is of the universal watery sphere, the other of the particular.

That of the universal is that which serves for all the waters that are without movement, which are in themselves in great quantity such as canals, ditches, ponds, fountains, wells, stagnant rivers, lakes, marshes, swamps and seas; for these although of different depth in themselves have the boundaries of their surfaces equidistant from the centre of the world, as are the lakes situated at the tops of high mountains, as above Pietra Pana and the lake of the Sybil at Norcia, and all the lakes which form the sources of great rivers, as the Ticino from Lake Maggiore; the Adda from Lake Como; the Mincio from Lake Garda; and the Rhine from Lake Constance and Coire, and from the lake of Lucerne; and as Trigon which passes through Africa Minor, which carries with it the water of three swamps at different altitudes one after another: of which the highest is Munace, the middle one is Pallas and the lowest is Triton. Again, the Nile has its source in three very high lakes in Ethiopia: it runs to the north and discharges itself into the Egyptian sea with a course of four thousand miles, and its shortest and most direct line which is known measures three thousand miles; it issues forth from the Mountains of the Moon from divers and unknown beginnings; and comes upon the said lakes high above the watery sphere at an altitude of about four thousand braccia, that is a mile and a third, in order to allow for the Nile falling a braccio in every mile. And the Rhone issues from the lake of Geneva and flows first west then south with a course of four hundred miles, and empties its waters in the Mediterranean sea.

The centre of a particular sphere of water is that which occurs in the tiniest particles of dew, which are seen in perfect roundness clustering upon the leaves of the plants on which it falls; it is of such lightness that it does not flatten itself upon the spot on which it rests, and it is almost supported by the atmosphere that surrounds it, so that it does not itself exert any pressure or form any foundation; and for this reason its surface is drawn to itself equally from every side with equal force; and so each part runs to meet another with equal force, and they become magnets one of another, with the result that of necessity each becomes of perfect roundness, forming its centre therefore in the middle at an equal distance from each point of its surface, and being pulled asunder equally by each part of its gravity, always placing itself in the middle between opposite parts of equal weight. But as the weight of this particle of water comes to be increased, the centre of the curved surface immediately emerges from this portion of water, and makes its way towards the centre of the common sphere of the water; and the more the weight of this drop increases the nearer the centre of the said curve approaches towards the centre of the earth.

Leic. 34 v.

I have seen in the case of two small canals each of a breadth of two braccia, which serve as a line of demarcation between the road and the estates, how their waters clashed together with unequal force, and then united, and bent at a right angle, and passed underneath a small bridge by this road and continued their course. But what I want to refer to in them is the fact that they formed there a flow and ebb, with a height of a quarter of a braccio, caused, now by one, now by the other canal, as will be stated. The first canal, being the more powerful, subdued the onrush of the water of the opposite canal, and by adding to it from the opposite direction caused it to swell up; and then the water coming above this from the swollen river, rose up in such a way as to acquire so much weight from the more sluggish water that it overcame the impetus and power of the water which at first was more powerful, and so drove it back with great fury; and consequently the victor, redoubling the impetus of its movement, entered with an undulation extending over more than a hundred feet into the more powerful canal, which at that time retarded and held up such of its waters as were at the boundary of the conquering wave. And from this wave upwards the river massed together so much water that after the end of the aforesaid impetus of the wave, these waters gained the victory and drove back the first waters; and so they continued in succession, without ever retarding the movement of that third canal in which they were united under the aforesaid bridge.

For this canal had four different movements, of which the first and second were with greater or less current, and the others according as it varied from the right to the left bank. The variation from the greater to the less current occurred when one of the streams of water made itself victor over the other, for as this other is turned back together with that which drives it an abundance of water is created under the bridge. The fall of the water under this bridge took place when the one stream of water which conquered the other had almost consumed its impetus and the opposing stream was left with its force already exhausted; the water under the bridge was then extremely low. The changing across of the current from the right to the left bank occurred when the water on the right or the left was victor, that is when the water on the right was victor the current struck against the left bank, and when the current in the canal on the left was victor it struck upon the right bank underneath the aforesaid bridge.

And if this ebb and flow created within so small a quantity of water has a variation of a quarter of a braccio, what will it be in the great channels of the seas which are shut in between the islands and the mainland?

It will be so much the more in proportion as its waters are greater.

Leic. 35 r.

OF THE WAVES OF WATER

The wave of water created by the wind is slower than the wind that moves it, and swifter than the current of the water that produces the wind; of this there is an example in the waves of the meadows.

The wave of the water created by the descent of the rivers is slower than the current of the water that produces it; and this happens because the wave in such rivers is formed from the bottom of this river, or from its sides, and it stands as firm as is the firmness of the object that produces it, while the water, which continually forms itself into a wave, is continually escaping from this wave.

There are many occasions when the wave of the water and that of the wind have the same course; and many occasions when they are contrary, intersecting at right angles or often at acute angles.

The movement of the falling wave penetrates into the movement of the wave recoiling. The wave of the water in a circular vessel runs from the edge to the centre and is then bent back from the centre to the edge and from the edge to the centre; and so it continues in succession.

The wave of a triangular vessel, or a vessel with sides, has not uniformity of time, because its sides and angles are not equidistant from the centre of the vessel.

The circle of the wave made by an object in running water will be oval in shape. Leic. 36 v.

XXII

Hydraulics

'To make water rise and remain upon the ascent.'

[*With drawing of pump*]

For the bath of the duchess Isabella; *a* Spring.

Made for the stove or bath of the duchess Isabella; *a* is in this position because the screw does not turn with its socket. C.A. 104 r. b

[*With drawings*]

Water raised by the force of the wind.

This syringe has to have two valves, one to the pipe which draws the water and the other to that which ejects it.

Method of making water rise to a height.

In this way one will make water rise through the whole house by means of conduit pipes. C.A. 386 r. b

OF THE FALL OF A RIVER

[*With sketch*]

If you should wish to know what the fall of a river is in each mile without employing any other instrument for observing levels, you should follow this method:—Be careful to choose a part of the river which has the most conformity with the general range of the course of which you wish to know the fall, and take in it a hundred braccia of bank of which the beginning and the end are marked by two rods, as is shown above in *a b*, and at the beginning *a* launch a bladder, oak-apple, or small piece of cork, and observe how many beats of time the aforesaid object travelling with the descending wave takes to arrive at the end of the journey of the hundred braccia, and then measure many other courses, some slower and some more rapid, and afterwards measure the fall of the hundred braccia with the instrument for observing levels. And by this process, having measured different reaches of the water, you will then know how to speak only for over a hundred paces of a bank; and by observing how many beats of time your oak-apple has taken to traverse this course you will be able to calculate the fall that it makes per mile. Tr. 56 a

[*With drawing of apparatus for raising water*]

If you wish to make water rise a mile and to cause it to rest upon a mountain do as is represented above. And if you wish the stream of water to be as big as your leg make the conduit as big as your thigh. And if it is to rise a mile make it also descend two miles, and then the violence of the water which is found between *b* and *c* will be so great that it will draw up the water which is found in *d e* and will turn the wheel of the water pump. And you must know that no air can enter into the water chamber by the water pump, seeing that every time that the screw of the water pump turns back, the valve which is at the bottom of the reservoir closes, and even if it were not so well stopped up it could not admit the air because it finds itself two braccia under water, and consequently could not admit air unless it first admit the two braccia of water. When you wish to fill the conduit you must first of all have a small lake filled with rains, and stop up with clay the pipes at the base of it, that is at *c* and *e*, and then let this lake discharge itself into the conduit. When the water has risen half a braccio up the wheel close the box tightly and then at the same time unstop the conduit at its base in *c* and make the wheel four braccia. B 26 r.

[*Drawing of machine*]

To raise water. B 54 r.

[*Hydraulic machine*]

If twelve ounces of water produce thirty thousand revolutions of a machine in an hour we believe that twenty-four ounces will produce sixty thousand revolutions per hour of the same machine if it has the same fall, and that the output will be double what it was at first.

H 90 [42] v.

[*Drawing*]

OF THE INSTRUMENT ABOVE

Let *a b* be stagnant water, let *a c* be a screw which is turned by the distaff *z*, and the said screw carries the water into the chamber *c f*, and from the said chamber a siphon tube proceeds which carries the water to another chamber which is round the centre of the wheel of the first movement, and from there the eight spokes take the water, which after it has fulfilled its function falls back to the spot from whence it started.

Forster I 41 r.

[*Drawing*]

a the instrument above:

m keeps *c* unstopped as long as it falls, and when *m* departs *c* closes, and when *m* comes to the bottom *s* goes to the top and draws after it the water of the well. Forster I 41 v.

[*Drawings*]

The water after issuing from the pump runs by the line *a c*, and pauses at *s*, and there makes counterpoise and falls down together with the lever *n m*, and draws up fresh water, of which part goes in counterpoise and part remains up by the line *b f*.

The water departs from the centre *a* and flows in *b*, and from *b* as far as *c* it makes a level lever, and from *c* it rises by the wheel of the screw gently and returns to the centre *c*; and make it with sixteen spokes.

Let *a b* be the level of the earth, *p* is the lever of *m*, *q* is that of *n*, and thus first one then the other after the manner of bellows perform their function.

This as far as relates to the cause of its movement has similarity with that above, and it varies only in that screw in the centre which conducts the water upwards. Forster I 42 r.

[*Drawings*]

Here the water having ascended by the screw will arrive by the pipe *s* at the point *a*, and from *a b* it will make equidistant lever, and from *b n* will return to the first screw, and will always repeat the same process, and above all it makes it wider at the end than at the beginning.

The screw *a* gives the water to the screw *b*, and the screw *b* gives movement with the same water to the screw *a*. Forster I 42 v.

[*With drawings*]

The water that falls from the mouth *g* comes from the chamber *f* pressed by the lead *d*, and when the chamber *f* is empty the water will be raised into the chamber *a* by a valve which opens inwards. Consequently as the part below becomes lighter and the part above heavier it suddenly turns right over and the lead *c* presses the chamber *a* and so it is always in motion. Forster I 45 v.

The left chamber sends its water from *f* in *b* and in this *b* there is a valve opening inwards, by means of which the chamber *c b a* comes to be filled, and the air escapes by *a n*; but make the mouth *a* higher than the other part so that the water may not pour out. The chamber *d* will be full of air and the part *e* will be lead. When the chamber *a b c* shall be full it will turn right over and the lead will remain above and will press the water on the left, and by the time that the water has made its exit the lead will have gone below and the chamber will receive the water from the right through *m s*. Forster I 46 r.

[*With drawings*]

To make water rise and remain upon the ascent. Forster I 50 v.

This water rises by way of a pump, and after issuing forth at the extremity of this pump it runs by the lever from *c a* and from *f b*, and having arrived at the extremity of the said lever the water that follows creates counterpoise. Forster I 51 r.

The water rises by the screw *a b* and falls in the chamber *c*, and from there it is drawn off by the siphon *b f* and carried into the chamber *p*, and from there until counterpoise is made in *s*, and then it falls into the stagnant water below.

This wheel with the lever *a n* will turn and draw the water with the circle. But see that when the buckets are ten you make twelve of the lever and one of the counterlever. Forster I 51 v.

XXIII

Canalization

'Every large river may be led up the highest mountains on the principle of the siphon.'

CANAL OF FLORENCE

[*Plan on which are the words Florence, Prato, Pistoia, Serravalle, Lago, Lucca, Pisa*]

Let sluices be constructed in the Val di Chiana at Arezzo, so that in summer when there is a shortage of water in the Arno the canal will not become dried up, and let this canal be twenty braccia wide at the bottom and thirty at the surface and the general level two braccia or four, because two of these braccia serve the mills and the meadows. This will fertilise the country, and Prato, Pistoia and Pisa, together with Florence will have a yearly revenue of more than two hundred thousand ducats, and they will supply labour and money for this useful work, and the Lucchesi likewise. Since the Lago di Sesto will be navigable make it pass by way of Prato and Pistoia and cut through at Serravalle and go out into the lake, for then there will be no need of locks or supports, which are not permanent but require a constant supply of labour to work them and to maintain them. C.A. 46 r. b

And know that this canal cannot be dug for less than four denari per braccio, paying each labourer at the rate of four soldi per day. And the time of construction of the canal should be between the middle of March and the middle of June, because the peasants are not then occupied with their ordinary work, and the days are long and the heat does not prove exhausting. C.A. 46 v. a

[*Plan of canal ascending hill by means of locks*]
[*Below*: 10 *braccia deep and* 8 *wide*]

Every large river may be led up the highest mountains on the principle of the siphon.

If the river *c d b* sends out a branch at the point *a* and it falls back again at the point *b*, the line *a b* will have so much greater pressure than the line *a c* that it will be able to take away so much of it as will serve to lead ships up mountains. C.A. 108 v. a

If a canal of water passes beneath another river with a bend like that of a knee, it exerts pressure in its desire to lift the cover of its conduit. Now I ask what weight is required to resist the weight of the water that wishes to proceed in its course. C.A. 199 v. b

OF A GOVERNOR OF RIVERS

In order to enable each large river to maintain itself within its banks, it is necessary for an official to be appointed with authority to command the people who live near to it, and so to effect repairs whenever it has burst its banks.

OF THE MAINTAINING OF RIVERS

The river which has the straightest course will best keep within its banks. C.A. 297 r. b

A trabocco is four braccia, and a mile is three thousand of these braccia, and the braccio[1] is divided into twelve inches . . . and the water of the canals has a fall of two inches in every hundred trabocchi. Therefore fourteen inches of fall are necessary in two thousand eight hundred braccia of movement of the said canals. It follows that fifteen inches of fall give the necessary momentum to the current of the water of the said canals, that is one and a half braccio to the mile; and by this we may conclude that the water which is taken from the river of Villefranche and is lent to the river of Romorantin would require . . .

Where by reason of its lowness a river cannot enter into another it is necessary to raise it by a dam to such a height that it can descend into the one which was the higher at first.

From Romorantin as far as the bridge at Saudre it is called the Saudre; and from that bridge as far as Tours it is called the Cher.

[1] Braccio—nearly two English feet.

[*Map of rivers*] Mon Ricardo. Romorantin. Tours. Amboise. Blois. Lyons.

You will make a test of the level of that canal which is to lead from the Loire to Romorantin by means of a channel one braccio wide and one braccio deep.

[*Map of rivers*] Era (Loire). Scier (Cher). Villefranche. Bridge of Saudre. Saudre. Ship.

On the Eve of Sant' Antonio I returned from Romorantin to Amboise, and the King [of France][1] departed two days before from Romorantin. C.A. 336 v. b

The canals of Milan have a fall of one braccio or thereabouts in every mile. And an inch a mile is found sufficient in respect to the surface movement of the water.

Moreover reckoning a fall of a braccio in every mile, in a space of four hundred miles it would become necessary for the water to turn back, because the world . . . C.A. 352 v. a

Let the Guild of the Wool Merchants construct the canal and take the receipts, making the canal pass by way of Prato, Pistoia, Serravalle and empty itself into the lake; and it will be without locks and more permanent and will produce more revenue from the places through which it passes. C.A. 398 r. a

The roots of the willows do not suffer the banks of the canals to be destroyed; and the branches of the willows, nourished during their passage through the thickness of the bank and then cut low, thicken every year and make shoots continually, and so you have a bank that has life and is of one substance. F 1 r.

When the pool that is [provided] for the month of June is empty, stop up the mouths and bend the river which has poured itself into it, and give it its outlet in the fall of the mill. F 13 r.

Make a lock to the narrow canal that comes from the sea, in order to be able to close it against storms and the tide and to open it at the ebb. F 16 r.

[1] MS. *di fran* crossed out.

IN ORDER TO DEEPEN A CANAL

Make this in the book of the aids, and in order to prove it cite the propositions that have been proved. And this is the true order, because if you wished to supply a help to each proposition it would still be necessary for you to make new instruments in order to prove this utility; and by so doing you would confuse the order of the forty books and so also the order of the figures; thus you would have to blend practice with theory, which would cause confusion and lack of continuity. F 23 r.

A great weight may be deposited upon a ship without the use of windlasses, levers, ropes, or any force:

In order to deposit each very heavy weight that is all in one piece upon a floating barge, it is necessary to draw this weight to the shore of the sea, setting it lengthwise to the sea at the edge of the shore. Then a canal should be made to pass beneath this weight and to project as far beyond it as the half of the length of the barge which is to carry this weight; and in like manner the width of this canal should be regulated by the width of the barge, which should be filled with water and drawn beneath the weight. And then after the water has been baled out the ship will rise to such a height as to raise the said weight from the ground of itself. Thus laden you will then be able to draw it to the sea and lead it to the place that is prepared for it. F 49 v.

OF THE CANAL OF MARTESANA

By the making of the Martesana canal the amount of water in the Adda is lessened owing to it being distributed over many districts in order to supply the meadows. A remedy for this would be to make many small channels because the water which has been drunk up by the earth does no service to anyone, nor any injury because it has been taken from no one; and by the construction of such channels the water which before was lost returns again and is once more of service and use to mankind. And unless such channels have first been constructed it is not possible to make these runlets in the lower-lying country. We should say therefore that if such channels are made in the Martesana, the same water, drunk in by the soil of the meadows, will be sent back upon the other meadows by means of runlets, this being water which had previously disappeared; and if there were a scarcity of water at Ghiara d'Adda and in the Mucca and the inhabitants were able to make these channels it would be seen that the same water drunk in by the meadows serves several times for this purpose. F 76 v.

CANALS CONCAVE AND CONVEX

It is possible that in a canal concave in its length the water flows with uniform depth.

It is impossible for the water in a convex canal to flow with uniform volume although the canal is of uniform width. F 88 v.

THE CANAL OF MARTESANA

A fall of two inches every hundred trabocchi, and these hundred trabocchi are four hundred and fifty braccia.

The greatest depth of the rivers will be beyond the current where the water is at rest. H 65 [17] r.

The more the water falls, the more it leaps.

On the second day of February, 1494, at the Sforzesca I have drawn twenty-five steps, each of two thirds of a braccio high and eight braccia wide.

The greatest depth of water will be between the percussion and the gurglings which result from it. H 65 [17] v.

No sluice should be narrower than the general width of the canal, because the water in this event forms eddies and breaks the bank.

H 76 [28] v.

[*Estimate for canal*]

The canal which is sixteen braccia in width at the bottom and twenty at the top may be said to average eighteen braccia over its whole width; and if it is four braccia in depth and costs four denari per square braccio it will cost per mile for excavation alone nine hundred ducats, the square braccio being calculated in ordinary braccia.

But if the braccia are such as are used to measure land, of which every four are four and a half, and if the mile consists of three thousand ordinary braccia and these are converted into those used to measure land, then these three thousand braccia lose a quarter so that there remain two thousand two hundred and fifty braccia; and therefore at four denari the braccio the mile comes out at six hundred and seventy five ducats; at three denari per square braccio the mile works out at five hundred and six and a quarter ducats, and therefore the excavation of thirty miles of the canal will work out at fifteen thousand one hundred and eighty seven and a half ducats. H 91 [43] r.

The water that falls over its embankments lays them bare and breaks them down on the opposite side. H 116 [27 v.] r.

GARDEN OF BLOIS

[*With diagram*]

a b is the conduit of Blois, made in France by Fra Giocondo; *b c* is what is lacking in the height of this conduit; *c d* is the height of the garden of Blois; *e f* is the fall of the siphon *b c e f*; *f g* is where this siphon discharges into the river.[1] K 100 [20] r.

RIVERS AND CANALS

[*With drawing*]

To ensure that the mouths of the canals which hollow themselves out from the rivers do not become filled up with shingle, and also to prevent the shingle from remaining in the middle of the dam that has been constructed against it, it should be made with a transverse descent. K 101 [21] r.

[*Canal of the Ticino*]

[*Diagram*]

The declivity of the canal with the small outlets at its bottom.

[*Diagram*]

All the water *a b* is that which enters into the canal having outlet

[1] This technical note as to the work of the Veronese architect Fra Giocondo in the garden of the château of Blois was most probably written by Leonardo while at Milan during the French occupation, the information having been supplied him by some member of the French court.

through the openings placed at the bottom; and all the water *a c* is that which enters in the canal having the openings near the surface of the water. The water *c b* having no outlet does not move its mass, and not moving it does not enter into the other mass but [this other] will go into the Ticino.

And in order thus to raise the openings make the course of the water more [less?] slanting, and make the course slower in consequence. Then this course in the same time draws a less quantity of water in the canal, and the mills receive less than at first although they receive the whole of it, and the outlets become full of impurities and choked up.

However I shall maintain the water in the canal at a height of one braccio and a half as at first, and the outlets at the bottom as at first, and I shall let in the water by degrees.

K 109 [29-30] r. and 108 [28] v.

[*Notes with drawing of section of Loire*]

LOIRE RIVER OF AMBOISE

The river is higher behind the bank *b d* than beyond this bank.

Island where there is a part of Amboise.

The river Loire which passes by Amboise passes by *a b c d*, and after passing the bridge *c d e* doubles back on its course by the canal *d e b f*, in contact with the embankment *d b* which comes between the two opposite movements of the above-mentioned river *a b c d*, *d e b f*. Then it turns back by the canal *f l g h n m* and reunites with the river from which it was formerly divided, which passes by *k n* and makes *k m r t*. But when the river is swollen it then runs all in one direction, passing the embankment *b d*. B.M. 269 r.

[*French canal—project*]

The main channel of the river does not take the turbid water, but this water runs in ditches on the outside of the town with four mills at the entrance and four at the exit; and this will be constructed by damming the water above, at Romorantin.

The water may be dammed up above the level of Romorantin at such a height that it works many mills in its descent.

The river at Villefranche may be led to Romorantin, and this may be done by the people who live there, and the timbers which form their houses may be taken on boats to Romorantin, and the river may be damned up at such a height that the water can be led down to Romorantin by an easy gradient.

[*Sketch map of Loire with tributaries*]

If the river *m n*, a tributary of the river Loire, were turned into the river of Romorantin with its turbid waters it would enrich the lands that it irrigated and make the country fertile, so that it would supply food for the inhabitants and it would also serve as a navigable canal for purposes of commerce.

HOW THE RIVER IN ITS COURSE SCOURS THE BED OF THE STREAM

By the ninth of the third: that which is swifter consumes its own bed more, and conversely the water that is slower leaves more behind of that which causes it to be turbid.

Therefore when the rivers are in spate you ought to open the flood-gates of the mills so that the whole course of the river may . . . there should be many floodgates for each mill so that . . . may open and give a greater impetus and thus the whole bed will be scoured.

And let the sluice be made movable like the one that I devised in Friuli, where when the floodgate was open the water which issued forth from it hollowed out the bottom; and below the two sites of the mills there should be one of these floodgates, one with movable sluices being placed below each of the mills. B.M. 270 v.

Here there are, my lord, many gentlemen who will undertake this expense between them, if so be that they are allowed to enjoy the use of the waters, the mills and the passage of ships; and when the price shall have been repaid them they will give back the canal of the Martesana.

Forster III 15 r.

That a river which has to be diverted from one place to another ought to be coaxed and not coerced with violence; and in order to do this it is necessary to build a sort of dam projecting into the river and then to throw another one below it projecting farther; and by proceeding in this way with a third, a fourth, and a fifth, the river will discharge itself in the channel allotted to it, or by this means it may be turned away from the place where it has caused damage, as happened in Flanders according to what I was told by Niccolò di Forzore.

[*With drawing*] How one ought to repair by means of a screen a bank struck by the water, as below the island of Cocomeri. Leic. 13 r.

FROM 'THE ORDER OF THE BOOK OF WATER'

No canal which issues forth from rivers will be permanent unless the water of the river from which it has its origin is entirely closed up, as is the case with the canal of Martesana and that which issues from the Ticino.

The canals ought always to be provided with sluices, so that excessive floods may not damage or destroy the bank and the water may always maintain itself in the same volume. Leic. 18 r.

How in order to twist the line of the water one should make a twist in the line of the bank with a few stones: By the fourth of the second, where it was proved that the line of the water of the rivers was a concourse of the reflex movements of the water that has struck upon its banks, and has there multiplied and raised itself and hollowed out its bed beneath itself. And this is what would occur if anyone set out to twist the bank when the river a certain space above had shown that it wished to bend, and then had not continued this bending process, and you were to follow it up again gradually and minister to its first desire with an almost imperceptible curve; and thus you will proceed to make your attempt. But if you should try to bend the water in the direct line of its strength all your work will be in vain, because it will break every obstacle. And if with your lock you raise the level of the water so high that it swallows up so much in itself that the current loses its impetus in the expanse of water that has been formed, this can have a good result, and, by the fifth of the first, it will fill up all its bed with mud. But make it so that the water does not run along the bank.

Leic. 27 v.

[*Of diverting a river and protecting a house*]

I have a house upon the bank of the river, and the water is carrying off the soil beneath it and is about to make it fall in ruin; consequently

I wish to act in such a way that the river may fill me up again the cavity it has already made, and strengthen the said house for me. In a case such as this we are governed by the fourth of the second, which proves that 'the impetus of every movabe thing pursues its course by the line along which it was created'; for which reason we shall make a barrier at the slant *n m*, but it would be better to take it higher up at *o p*, so that all the material from your side of the hump might be deposited in the hollow where your house is; and the material from the hump *k* would then do the same, so that it would serve the need in the same winter. But if the river were great and powerful the said barrier would have to be made in three or four attempts, the first of which, made in the direction that the water is approaching, ought to project beyond its bank a fourth part of the width of the river; then, below this, you should make another, distant as far as the summit of the leap that the water makes when it falls from the first barrier,—for in this summit of its leap the water leaves the summit of the mound made by the shingle which was hollowed out by the first percussion, made by the water when it fell from the first barrier upon its bed. And this second dam extends halfway across the breadth of the river. The third should follow below this, starting from the same bank, and at the same fixed distance from the second as the second was from the first; and it follows its length as far as three-quarters of the width of the river. And so you will proceed with the fourth dam which will close the whole river across. And from these four dams or barriers there will result much greater power than if all this material had been formed into one barrier, which in uniform thickness would have closed the whole width of the stream. And this happens by the fifth of the second, where it is proved that the material of one single support, if it be quadrupled in length, will not support the fourth of that which it used formerly to support, but much less.

[*Drawing*]

I find that the water, that falls at the foot of the dams of rivers, places material towards the approach of the water, and carries away from the foot of the dam all the material on which it strikes as it falls. Now I could wish that it would place the material where it falls, and thereby bank up and fortify this dam: which thing might be done in this way— Leic. 32 r.

XXIV

Experiments

'Take away that yellow surface which covers the orange and distil it in a retort until the extract is pronounced perfect.'

AN EXPERIMENT WITH THE SENSE OF TOUCH

If you place your second finger under the tip of the third in such a way that the whole of the nail is visible on the far side, then anything that is touched by these two fingers will seem double, provided that the object touched is round. C.A. 204 V. a

I take a vessel filled with wine and I draw off the half and fill it up again with water: in consequence the vessel will contain half wine and half water.

Then I draw off half again and then fill up with water, wherefore there remains . . .

Since every continuous quantity is divisible to infinity, if a quantity of wine be placed in a vessel through which water is continually passing it will never come about that the water which is in the vessel will be without wine. C.A. 218 r. b

TO KNOW THE NORTH SIDE OF THE MAGNET

If you wish to find the part of the magnet that naturally turns towards the north get a large tub and fill it with water; and in this water place a wooden cup and set in it the magnet without any more water. It will remain floating in the manner of a boat, and by virtue of its power of attraction it will immediately move in the direction of the north star; and it will move towards this, first turning itself with the cup in such a way that it is turned towards this star, and will then move through the water and touch the edge of the tub with its north side, as before mentioned. E 2 r.

[*With drawing*]

This globe should be a half or a third of a braccio in diameter; and it should be of clear glass and filled with clear water with a lamp in the middle, with the light in about the centre of the globe, and when suspended in the centre of a room it will give a great light.

F 23 V.

[*Sphericity of water. Experiment*]

A drop of dew with its perfect round affords us an opportunity of considering some of the varied functions of the watery sphere; how it contains within itself the body of the earth without the destruction of the sphericity of its surface. For if first you take a cube of lead of the size of a grain of millet, and by means of a very fine thread attached to it you submerge it in this drop, you will perceive that the drop will not lose any of its first roundness, although it has been increased by an amount equal to the size of the cube which has been shut within it.

F 62 V.

[*Light and heat. Sun and mirrors*]

Whether the greater light with less heat causes concave mirrors to reflect rays of more powerful heat than a body of greater heat and less light.

For such an experiment a lump of copper should be heated and placed so that it may be seen through a round hole, which in size and distance from the mirror is equal to the heated copper.

You will thus have two bodies equal in distance but differing in heat and differing in radiance, and you will find that the greater heat will produce a reflection of greater heat in the mirror than the aforesaid flame.

We may say therefore that it is not the brightness of the sun which warms but its natural heat.

It is proved that the sun in its nature is warm and not cold as has already been stated.

The concave mirror although cold when it receives the rays of the fire reflects them hotter than the fire.

A ball of glass when filled with cold water sends out from itself rays caught from the fire which are even hotter than the fire.

From the two experiments referred to, it follows, as regards this warmth of the rays that issue from the mirror or from the ball of cold water, that they are warm of their own essence, and not because the mirror or ball are hot. And in this case the same thing happens when the sun has passed through the bodies which it warms by its own essence. And from this it has been concluded that the sun is not hot, whilst by the experiments referred to it has been proved that it is extremely hot,—from the experiment which has been mentioned, of the mirror and of the ball which being cold and taking the rays of the heat of the fire convert them into warm rays because the primary cause is warm. And the same thing happens with the sun, which being itself warm, in passing through these cold mirrors reflects great heat.

F 85 v.

HOW TO MEASURE THE THINNESS OF WATER. EXPERIMENT

You will discover the various degrees of thinness of the waters by suspending at a uniform depth of the opposite ends a strip of old linen cloth, which should be dry, and which should penetrate on each side as far as the bottom of two vases filled with the two different kinds of water with which you wish to make your experiment. Then these waters will rise a certain distance on the cloth and will proceed gradually to evaporate, and as much as has been the evaporation of that which has risen up, so much will it rise again from the rest until the vase is dried up. And if you refill the vase the water will all rise in the piece of cloth with imperceptible slowness, and so as has been said it will gradually become dried up. And by this means the piece will remain full of the rest of the water which has evaporated, and in this way, by means of the weights that have been acquired, you will be able to tell which water holds more earth in solution than the other. G 37 v.

OF THE SIPHON WITH MERCURY FOR MAKING FIRE

Since the more the water in the vessel diminishes the more its surface is lowered, and the more the surface of the water is lowered the less swiftly the siphon flows, but if the siphon descends at the same time as the surface of the water that supports it, without doubt the movement of the water which pours through will always be equal in itself, therefore in order to make this equality let us make the vessel *n* in position above the bath of mercury *m*. This vessel *n* is a boat which supports the siphon which penetrates below from the air into the mercury. And this mercury proceeds to rise through the siphon *n s t* into the vessel *f*. And in proportion as the surface of this mercury descends so the boat which rests upon it descends at the same time as the siphon, which is formed of fine burnished copper and falls into a vessel, and this when it acquires the requisite weight falls and thereby creates fire by its impact. G 48 r.

One may finds by experiment whether if untarnishable varnish be melted by the fire it moves from slanting positions if it is not of great thickness,—this varnish after it has been liquefied should be smoothed constantly with a brush. G 73 v.

[*The flowing of liquids*]

If a cask is filled four braccia high with wine and throws the wine a distance of four braccia away, when the wine has become so lowered that it has dropped to a height of two braccia in the cask, will it also throw the wine through the same pipe a distance of two braccia, that is whether the fall, and the range that the pipe can throw, diminish in equal proportion or no.

If from the cask when full two jugs are filled through the pipe in an hour, when the cask is half full it ought for this reason to fill only one jug in an hour, if pouring from the same pipe.

This rule with all the other similar ones about waters which are poured through pipes ought to be put at the commencement of the instruments, in order to be able through various rules the better to proceed to the proofs of these instruments. I 73 [25] r.

[*Good or poor mathematician*]

In order to make trial of anyone and see whether he has a true judgment as to the nature of weights, ask him at what point one ought to cut one of the two equal arms of the balance so as to cause the part cut off, attached to the extremity of its remainder, to form with precision a counterpoise to the opposite arm. The thing is never possible, and if he gives you the position it is clear that he is a poor mathematician. M 68 v.

Cause an hour to be divided into three thousand parts, and this you will do by means of a clock by making the pendulum lighter or heavier. B.M. 191 r.

FIRE

If you wish to make a fire which shall set a large room in a blaze without doing any harm you will proceed thus: first perfume the air with dense smoke of incense or other strongly smelling thing, then blow or cause to boil and reduce to steam ten pounds of brandy.

But see that the room is closed altogether, and throw powder of varnish among the fumes and this powder will be found floating upon the fumes; then seize a torch and enter suddenly into the room and instantly everything will become a sheet of flame. Forster I 43 r.

Take away that yellow surface which covers the orange and distil it in a retort until the extract is pronounced perfect.

Close up a room thoroughly and have a brazier of copper or iron with a fire in it, and sprinkle over it two pints of brandy a little at a time in such a way that it may be changed into smoke. Then get someone to come in with a light and you will see the room suddenly wrapped in flame as though it was a flash of lightning, and it will not do any harm to anyone. Forster I 44 v.

[*Experiment with waves of water and of air*] [*With figures*]

Place yourself in a boat and construct an enclosure *n m o p* and fix within it two pieces of board *s r* and *t r*,[1] and make a blow at *a* and see whether the broken wave passes with its suitable part as far as *b c*.[2]

And from the result of the experiment which you make with the wave cut off by the circular wave of the water, may be inferred what happens with that portion of the wave of air which passes through the airhole through which the human voice passes when confined in a box; as I heard at Campi from a man who had been shut up in a cask with the bunghole left open. Quaderni III 12 v.

[1] As figure shows, these two pieces of board are placed opposite to each other at right angles to the sides of the enclosure and are each about a third of its width.

[2] The lines *b a*, *c a* form an acute angle with equal arms which pass through the ends of the two boards *s r* and *t r* and continue to the points *b* and *c*, which are near the sides of the enclosure.

XXV

Inventions

'O speculators about perpetual motion, how many vain chimeras have you created in the like quest? Go and take your place with the seekers after gold.'

[*With drawing*]

Method of drying up the marsh at Piombino. C.A. 139 r. c

[*Diagrams*]

Here there is need of a clock to show the hours, minutes and seconds (*l'ore punti e minuti*).

For measuring how great a distance one goes in an hour with the current of the wind.

For learning the quality and density of the air and when it will rain.

For reckoning the mileage of the sea. C.A. 249 v. a

[*With drawing*]

This is the way to dredge a harbour, and the plough *m n* will have in front of it spikes shaped like ploughshares and knives, and this plough will be used to load a large cart with mud. The cart will have its back perforated after the manner of a net in order that the water may not be shut within the box; and the said plough is to be moved along above the place where the mud is to be dug out, and along with it a barge; and when it has reached the bottom the windlass *b* will draw it underneath the windlass *a*, and the windlass *a* will raise it up when it is full as far as its beam, in such a way that there will be room for the barge to go underneath it and take the mud from the plough; and so this plough will be able to dislodge the mud from the bottom and unload it upon the barge which is placed underneath it.

C.A. 307 r. b

Make to-morrow out of various shapes of cardboard figures descending through the air, falling from our jetty; and then draw the figures and the movements made by the descent of each, in various parts of its descent. C.A. 375 r. c

[*With drawings*]

These scissors open and shut with a single movement of the hand.

Scissors used by the bonnet-makers for cutting cloth. Rapid in the action of opening and shutting like the others.

This [tool] has in itself so much more ease in its movement because the user does not have to adjust the spring or curve, as is the case with those scissors which are all in one piece. With these it is not necessary to wait in order to cut the threads of the cloth, or to bend by force the spring which is in the heel of the scissors.

This closes at the same rate of speed as the rest; but opens much more rapidly. C.A. 397 v. a

[*Drawing of apparatus with ropes and pulleys*]

Method of raising and lowering the curtains of the treasures of silver of the lord. Tr. 6 a

[*With drawing of tube descending from surface of water to cover mouth of man in diving dress*]

This instrument is employed in the Indian Ocean in pearl fishing; it is made of leather with numerous rings so that the sea may not close it up. And the companion stands above in the boat watching, and this [diver] fishes for pearls and corals, and he has goggles of frosted glass and a cuirass with spikes set in front of it. B 18 r.

A WAY OF SAVING ONESELF IN A TEMPEST OR SHIPWRECK AT SEA

[*With drawing*]

It is necessary to have a coat made of leather with a double hem over the breast of the width of a finger, and double also from the girdle to the knee, and let the leather of which it is made be quite air-tight. And when you are obliged to jump into the sea, blow out the lappets of the coat through the hems of the breast, and then jump into the sea.

And let yourself be carried by the waves, if there is no shore near at hand and you do not know the sea.

And always keep in your mouth the end of the tube through which the air passes into the garment; and if once or twice it should become necessary for you to take a breath when the foam prevents you, draw it through the mouth of the tube from the air within the coat.

B 81 v.

[*Alarum-clock*] [*With drawing*]

A clock to be used by those who grudge the wasting of time.

And this is how it works:—when as much water has been poured through the funnel into the receiver as there is in the opposite balance this balance rises and pours its water into the first receiver; and this being doubled in weight jerks violently upwards the feet of the sleeper, who is thus awakened and goes to his work. B 20 v.

[*Drilling machine*]

In order to drill through a beam it is necessary to hold it suspended and drill from below upwards so that the hole may empty of itself, and you should make this canopy so that the sawdust may not fall upon the head of him who turns the screw; and see that the turners rise at the same time as the said screw. And make the hole first with a fine auger and then with a larger one. B 47 v.

[*Drawing*]

A sledge for use in mud. And make the part that comes upon the ground united in order that it may not get stuck in the mud.

B 49 v.

[*Drawing*]

A sledge for use in mountainous and rocky places. And do not make the part that touches the ground united, so that it may be less difficult to drag; for the less the weight touches the less difficult it is to move.

B 50 r.

[*Timepiece. With drawing*]

Four springs for a timepiece, so that when one has finished its course the other commences, and as the first turns the second remains motionless. And the first is fixed above the second like a screw, and when it is fixed the second spring takes the same movement completely and so do all. B 50 v.

[*With drawing*] [*Paddle-boat*]

Barge made of beams and covered over above. But make a large wheel of oars concealed within it, and make a furrow from one end of it to the other, as appears in *a*, where the wheel can touch the water.

B 76 V.

[*To make concrete*] [*With drawings*]

a is a box which can open and empty itself, and in it you can make a concrete formed of fine pebbles and chalk. Let these blocks dry on the ground and then place them one upon another under the water, in order to form a dam against the rush of the water.

Frames filled with gravel and twigs of birch, that is a layer of twigs [*sketch*] placed vertically in this direction and a layer of gravel, then a layer in this contrary direction [*sketch*] and then a layer of gravel, and thus you will construct it bit by bit. B 79 V.

OF PROPORTION

See if there are a number of small stones of different sizes whether the heaviest goes farthest when one throws it, then try alone with the same instrument and force, and see whether it travels a greater or less distance alone than when accompanied. And whether also if the stones are all of the same form and weight, like the balls of an air-gun, and are thrown by the same force in the same time they travel the same distance.

BELLOWS WITHOUT LEATHER AND MERELY OF WOOD

These bellows are like a sugar loaf and have a partition which divides them lengthwise in two parts. One—that is the upper part—is filled with water; that below is filled with air. The water falls down into the cubic space of the air through a small hole which is near the socket, and the increase of the water drives the air through the mouth of the bellows. Any scarcity of water in the upper part is filled by means of a valve which admits the air, and so also with the others; and this is the most serviceable type of bellows that can be used.

B 81 R.

Webbed glove for swimming in the sea. [*With drawing*]

B 81 V.

[*Water bellows*] [*Drawings*]

These are kinds of bellows without leather and they are of admirable utility and extremely durable. And their method of use is as follows:—The bellows is always from the centre downwards full of water, that is *M N*, and in the continual revolution of the bellows *N* rises until it reaches the air hole *S T* which is made in the outside of the second covering, as appears in the instrument below, and comes to meet with the said pipe *S T* the hole *o* which is in the reservoir *N*, and as much as is the volume of water that goes from *N* to *M* so much air enters through the hole *o* in the reservoir *N*, and as much air is driven out of the reservoir *M* as *N* gives it of water. And the air which is driven out from *M* by the water is that which blows the bellows. The said bellows should be of oak because this resists water for the longest time, and have inside it a coating of turpentine and pitch, so that when it is not in use the part above which is out of the water does not come to open; and this type of bellows is turned by the weight of a man walking above on the steps.

It would also be extremely useful to cause it to turn by the force of a fall of water.

The base of the bellows below the tube *S T* remains fixed, and the rest turns there within as a case would within its cover.

Use salt water so that it may not become foul in the bellows.

B 82 r.

[*With drawings of machine*]

To produce a marvellous wind. E 33 v.

The current will be so much the more abundant as the small doors open with less descent. (*discesa*? MS. *dissci* . . .)

The whole space of the small doors is equal to the whole space of the width of the pipe. E 34 r.

MACHINE FOR EXCAVATING EARTH

[*Drawing*]

Here the calculation of the power is not at present fixed.

But you, reader, have to understand that this has a use, which arises by means of the saving of time, which saving springs from the fact that the instrument which conveys the earth up from below is always in the act of carrying it and never turns back. The adversary says that in this case it takes as long to turn round in a useless circle as to turn back at the end of the forward action. But since the additional spaces of time that are interposed between the spaces of useful time are equal in this and in all other inventions, it is necessary to search here for a method whereby the time may be spent in as vigorous and effective a method of work as possible, which will be by inventing a machine that will take more earth; as will be shown on the reverse of this page.

The winch *n* as it turns causes a small wheel to revolve, and this small wheel turns the cogged wheel *f*, and this wheel *f* is joined to the angle of the boxes which carry the earth from the swamp and discharge themselves upon the barges. But the two cords *m f* and *m b* revolve round the pole *f*, and make the instrument move with the two barges against *m*, and these cords are very useful for this purpose.

The pole is so made as to descend to as great a depth as the wheel has to descend in order to deepen the water of the marsh. E 75 V.

As the attachment of the heavy body is further from the centre of the wheel the revolving movement of the wheel round its pivot will become more difficult although the motive power may not vary.

The same is seen with the time of clocks, for, if you place the two weights nearer or farther away from the centre of the timepiece, you make the hours shorter or longer. F 7 V.

[*Magnifying glasses*]

Lens of crystal thickness, at the sides the twelfth part of an inch. This lens of crystal should be free from spots and very clear; and at the sides it ought to be the thickness of a twelfth of an inch, that is to say of the one hundred and forty-fourth part of a braccio, and thin in the centre according to the sight that it ought to serve for, that is to say according to the proportion of those lenses which agree with it; and let it be worked in the same mould as these lenses. The width of the frame will be one sixth of a braccio and its length one quarter of a braccio; consequently it will be three inches long and two wide, that is to say a square and a half. And this lens should be held at a distance of a third of a braccio from the eye when used, and it should be the same distance from the letter that you are reading. If it is farther away this letter will appear larger, so that the ordinary type of print will seem like a letter on an apothecary's chest.

This lens is suitable for keeping in a cabinet; but if you wish to keep it outside make it one eighth of a braccio long and one twelfth wide.

F 25 r.

[*A pedometer*] [*Figure*]

In order to know how far one goes in an hour take the potter's wheel constructed as you see, and place above the instrument, of which the centre may be upon a circular line which turns exactly five braccia, the diameter being one and $\frac{12}{22}$ braccia. Then tightly close the instrument, have harmonic time, smear all the inside of the instrument with turpentine, turn the wheel uniformly and notice where the top layer of dust has stuck to the turpentine, and see how many revolutions the wheel has made and in how many beats of harmonic time. And if the wheel has made two revolutions in one beat of time, which amounts to ten braccia, that is to say the three-hundreth part of a mile, you will be able to say that this instrument has moved a mile in three hundred beats of time, and that an hour is one thousand and eighty beats of time; which will make three miles an hour and one hundred and eighty three-hundredth parts. F 48 v.

[*A decoration*]

If you make small pipes after the manner of goosequills, which are opaque and white with a coating of black within and then transparent, and with sardonyx outside and then transparent; and let all the thick portion of the pipes be made up of these mixtures, and then moisten them and press them and leave them to dry in the press; if you press them flat they will give one effect, if you press them into a rectangle they will give another and similarly if you press them into a triangle; but if you press them in front or folded in different ways you will also do well.

And if in the transparent part exposed to the sun you make with a small style a mixture of different colours, especially of black and white opaque, and yellow of burnt orpiment, you can make very beautiful patterns and various small stains with lines like those of agate.

F 55 v.

LAMP

[Drawing]

Lamp in which as the oil becomes low the wick rises.

And this proceeds from the fact that the wheel which raises the wick rests upon the oil. As the oil diminishes so the wheel descends, and as it descends it revolves by means of the thread that is wrapped round its axle, and the cogs of the wheel push the toothed pipe that receives the wick.

It will also do the same if *a* the axle of the wheel does not descend, and the only descent is that of the light object *b* which floats upon the oil, for this light object descends at the same time as the surface of the oil, and causes the wheel to turn, and this by means of its cogs pushes up the aforesaid cogged pipe with a slow movement.

G 41 r.

THE MINT OF ROME

[With drawings]

This can also be made without a spring, but the screw above must always be joined to the part of the movable sheath.

No coins can be considered as good which have not the rim perfect; and in order to ensure the rim being perfect it is necessary first that the coins should be absolutely round.

In order to make this it is necessary first to make the coin perfect in weight, breadth and thickness; therefore you must first have many plates made of this [uniform] breadth and thickness drawn through the same press, and these should remain in the form of strips, and from these strips you should stamp out the round coins after the manner in which sieves are made for chestnuts, and these coins are then stamped in the way described above.

The hollow of the mould should be uniformly and imperceptibly higher at the top than at the bottom.

This cuts the coins of perfect roundness, thickness and weight, and saves the man who cuts and weighs, and saves also the man who makes the coins round.

They pass therefore merely through the hands of the worker of the plate and the stamper, and they are very fine coins. G 43 r.

OF PERCUSSION

Among the accidental forces of nature, percussion greatly exceeds each of the others created by the motive powers of heavy bodies in equal time with equal movement, weight and force. This percussion is divided into simple and compound. Simple is that in which the motive power which is the striker is joined with the movable thing at its junction at the place struck; compound is that in which the movable thing as it strikes does not end its movement at the place of its impact, as does the hammer which strikes the die that stamps the coins. And this compound percussion is much weaker than simple percussion, for if the flat end of the head[1] of the hammer were to attach itself to the coin which it had to stamp and which it had struck upon the mould where was the impression, so that on this flat end of the head of the hammer there had been engraved the relief that was on the coin in reverse, the impression would be more definite and clear on the side struck with simple movement than on the side where the percussion is compound; as with the coin that remains struck in the die where the hammer has struck it in its descent, the percussion being reflected and thrown back against the front of the hammer.

G 62 V.

SIPHON CLOCK. SLOW TIME-FUSE

[*Of the siphon*]

A preparation of mercury drawn through very fine copper of the shape of a siphon, the sides through the length of which the liquid rises and falls being of imperceptible thickness, will be seen to form a time-piece after the manner of an hourglass, and this is the slowest and most graduated descent that can be made, so much so that it may happen that in an hour not one grain of the mercury passes from one vessel to the other.

And the surface of its container is sensitive by reason of the opacity of the mercury, the skin of this mercury becoming imperceptibly lowered with the descent that occurs as the siphon discharges itself; and by this means you will be able to create a fire which by means of per-

[1] MS. *bocha.*

cussion will generate itself at the end of a year or more, and this without any sound down to the moment of the creation of the fire.

And it is shown in the margin at the foot of the fourth page (folio 48 r.) how one ought to fix or set up this vessel, which by the power observed gives the result which is promised us at the end. G 44 v.

TO KNOW HOW FAR A SHIP TRAVELS IN AN HOUR

The ancients have employed different methods in order to discover what distance a ship traverses in each hour. Among them is Vitruvius who expounds one in his work on architecture, but his method is fallacious like the others. It consists of a wheel from a mill touching the ocean waves at its extremities, and by means of its complete revolutions describing a straight line which represents the line of the circumference of this wheel reduced to a condition of straightness. But this device is only of value on the smooth still surface of lakes; should the water move at the same time as the ship with an equal movement the wheel remains motionless; and if the movement of the water be either more or less swift than that of the ship, then the wheel will not have a movement equal to that of the ship, so that such an invention has but little value.

Another method may be tested by experiment over a known distance from one island to another, and this is by the use of a light board which is struck by the wind, and which comes to slant to a greater or less degree as the wind that strikes it is swifter or less swift, and this is in Battista Alberti.

As regards the method of Battista Alberti which is founded upon an experiment over a known distance from one island to another, such an invention will work successfully only with a ship similar to that with which the experiment has been tried, and it is necessary that it should be carried out with the same freight and the same extent of sail, and with the sail in the same position, and the waves of the same size. But my method serves with every kind of ship, whether it be with oars or sail; and whether it be small or large, narrow or long, high or low, it always serves. G 54 r.

[*With drawing*]

KEY OF THE BATH OF THE DUCHESS

Show all the ways of unlocking and releasing. Put them together in their chapter. I 28 v.

BATH

To warm the water of the stove of the duchess add three parts of warm water to four parts of cold water. I 34 r.

[*With ground plan of Castle of Milan*]
A way of flooding the castle. I 38 v.

DRESS FOR CARNIVAL

To make a beautiful garment take fine cloth and give it a strong-smelling coat of varnish made of oil of turpentine; and glaze it with eastern [scarlet] kermes, having the stencil perforated and moistened to prevent it from sticking. And let this stencil have a pattern of knots, which should afterwards be filled in with black millet, and the background with white millet. I 49 [I] v

[*With drawing*]
Water-clock which sounds twenty-four hours and the water falls half a braccio.
Water-clock which shows the value [of time]. L 23 v.

[*With drawing*]
Water-clock.

[*With drawing of press*]
To press wine and oil in casks bound with iron. L 27 r.

[*Drawings*]
Machines for drying the trenches where the water has overflowed.
L 69 v.

CAMP-BED

[*With sketch*]

Four straps for the length and eight across.

And each of the straps to be buckled at one end and nailed at the other. L 70 r.

[*Movable bridge*]

[*Drawings*]

Bridge to draw horizontally with a windlass.

Let *a* be a pulley *b* the windlass.

c n will be a pavement of flagstones which has a tube beneath it through which the chain passes.

This is the front of the said bridge.

Here is a bridge which carries with it little wheels, and another, better, which travels on small wheels that remain fixed in one position.

a b is the part of the bridge that projects out of the wall; *b c* is the part that remains within. M 55 V.

[*Fittings of a stove*]

This is the lattice which comes between the eyes and the fire of the stove.

All the transparent part (*il netto*) has a breadth of a braccio and a quarter; and there are six thin boards but it is better that they should be of thin brass.

The opening two braccia high and the transparent part one braccio and a quarter wide.

You should divide it in height in two parts, so as to be able at will to open below and not above, in order to warm the legs.

In the lower part you should use six boards, so that they are wider below than above in order to be able to put the feet to warm; above there should be eight, to be able to put the hands which are narrower. M 86 r.

[*Diagram*]

To make a pair of compasses diminish or increase a portion of their measurement with equal proportion in each part.

Bind it spirally with a screw which has as much of it smooth as enters in the compasses and all the rest is carved spirally; and this screw may be changed at different places throughout the length of the compasses, because at different places there are holes equally distant from the extremities of these compasses, into which the screw can enter halfway as at *a*, a quarter as at *b*, and one eighth as at *c*; and so it proceeds through the whole, and it is bound by the nut *h* of this screw.

Forster I 4 r.

METHOD OF THE SMALL COMPARTMENTS OF THE ROUND MACHINE GIVEN BELOW

[*Drawing*]

Make it so that the buckets which are plunging with the mouth downwards have such an opening that the air cannot escape; it will also be a good thing that the covered exits to the buckets should be of terracotta so that they may be better able to pass beneath the water; and of copper would be best of all. Forster I 50 v.

[*Sketch of loom*]

Threads for weaving ought to be two braccia long.

[*Sketch*]

Thus one ought to lay the warp. Forster II 49 v.

Moreover you might set yourself to prove that by equipping such a wheel with many balances, every part however small which turned over as the result of percussion would suddenly cause another balance to fall, and by this the wheel would stand in perpetual movement. But by this you would be deceiving yourself; for as there are these twelve pieces and only one moves to the percussion, and by this percussion the wheel may make such a movement as may be one twentieth part of its circle, if then you give it twenty-four balances the weight would be doubled and the proportion of the percussion of the descending weight diminished by half, and by this the half of the movement would be lessened; consequently if the first was one twentieth of the circle this second would be one fortieth, and it would always go in proportion, continuing to infinity.

Forster II 89 v.

Whatever weight shall be fastened to the wheel, which weight may be the cause of the movement of this wheel, without any doubt the centre of such weight will remain under the centre of its axis.

And no instrument which turns on its axis that can be constructed by human ingenuity will be able to avoid this result.

O speculators about perpetual motion, how many vain chimeras have you created in the like quest? Go and take your place with the seekers after gold. Forster II 92 v.

[*Diagram*]

To try again the wheel which continually revolves.

I have many weights attached to a wheel at various places: I ask you the centre of the whole sum of the weight.

I take a wheel revolving on its axis, upon which are attached at various places weights of equal gravity, and I would wish to know which of these weights will remain lower than any of the others and at what stage it will stop. I will do as you see above, employing this rule for four sides of the circle, and that where you will see greater difference upon the arms of the balance, that is that experiment which will throw you the sum of one of the gravities more distant from the pole of the balance, that will go on and become stationary below; and if you want all the details repeat the experiment as many times as there are weights attached to the wheel. Forster II 104 v.

If you wish to make a boat or coracle strong, take . . . (*allume splumie*) and of these make fine cords and weave them together and do as one weaves the sacks after making oil of walnut, and of this cover your boat as you would with leather. Take from what is in the house, and test this by combing as with the sinew of the ox . . .

Forster III 35 r.

PAPER ON WHICH IT IS POSSIBLE TO DRAW IN BLACK WITH THE SALIVA

Take dust of oak-apple and vitriol and reduce it to a fine powder and spread this over the paper after the manner of varnish; then write on it with a pen dipped in the saliva and it will become as black as ink.

TO ADD WATER TO WHITE WINE AND SO CAUSE IT TO BECOME RED

Crush an oak-apple to a fine powder and stand it for eight days in white wine, and in the same way dissolve vitriol in water, and let the water and the wine settle well and become clear each of itself, and strain them well; and when you dilute the white wine with this water it will turn red. Forster III 39 v.

[*Sketch*]
To weigh the force that goes to turn the millstone with its corn. Forster III 46 v.

[*Sketch*]
To measure a fall of water. Forster III 47 r.

[*Sketch*]
For taking away and placing in position rafters for the framework of houses and for their roofs. Forster III 56 v.

[*Sketch*] [*Self-closing gate*]
On one side is the shutter. Forster III 58 r.

OF THE INSTRUMENT

Anyone who spends one ducat for the pair may take the instrument, and he will not be paying more than half a ducat as a premium to the inventor of the instrument and one grosso for the operator; but I have no wish to be an under-official. Forster III 61 v.

[*With drawing*]
Dry or moist vapour-bath, very small and portable, weighing twenty-five pounds. Quaderni II 9 v.

[*With drawings*]
A method of ascertaining how far water travels in an hour. This is done by means of harmonic time, and it could be done by a pulse if the time of its beat were uniform; but musical time is more reliable in such a case, for by means of it it is possible to calculate the distance that an object carried by this water travels in ten or twelve of these

beats of time; and by this means it is possible to make a general rule for every level canal. But not for rivers, for when these are flowing underneath the surface they do not seem to be moving above.

Leic. 13 v.

[*Drawing: with note 'lathe for potters'*]

How many miles an hour with a wind; and here one may see with the water of the mill which moves it how many revolutions the wheel which is about five braccia makes in an hour; and so you will make the true rule away from the sea, making the wheel go one, two, and then three times in the hour; and by this means you will regulate it exactly, and it will be true and good. Leic. 28 r.

[*Meat-roasting jack*]

Water which is blown through a small hole in a vessel in which it is boiled is blown out with fury and is entirely changed into steam, and by this means meat is turned to be roasted. Leic. 28 v.

[*Drawing: wheel on shaft with counterpoise on suspended looped cord*]

In order to see how many miles a ship can go in an hour have an instrument made which moves upon a smooth wheel together with this wheel, and so adjust the counterpoise that moves the wheel as to cause it to move for an hour; and you will be able to see how many revolutions this wheel makes in the hour. The revolution of the wheel may be five braccia, and it will make six hundred revolutions in a mile. And the glass should be varnished or soaped on the inside, so that the dust that falls from the hopper may attach itself to it; and the spot where it strikes will remain marked; and by this means you will see and be able with certainty [to discern] the exact height where the dust struck, because it will remain sticking there. Leic. 30 r.

XXVI
Warfare

'When besieged by ambitious tyrants I find a means of offence and defence in order to preserve the chief gift of nature, which is liberty.'

'I can noiselessly construct to any prescribed point subterranean passages either straight or winding, passing if necessary underneath trenches or a river.'

[*How to make a pontoon*]

Since every river current is swifter in the centre of its breadth than at its sides, and flows faster on its surface than in its bed when the course is equal, and a movable bridge made upon barges is in itself weaker in the middle of its length than towards the extremities, therefore I conclude that as the greater weakness of the bridge is accompanied by the greater percussion of the water this bridge will break in the centre.

Make it so that in the movement of the bridge the length of the barges will always find itself in line with the current, when the movement will be so much easier as the barges receive less percussion from the water. C.A. 176 r. c

[*Fortification*]

The tower must needs be massive as far as the end of the scarp, then in order that powder may not be thrown there you must make the windows high.

A WAY TO MAKE A CUIRASS

If you place between two thicknesses of cloth scales of iron[?] [1] and with this make a doublet you may take it as certain that no point will ever be able to penetrate. C.A. 358 v. a

[1] MS. *f. . . . .* (*ferro?*)

Again a bombard that takes a projectile weighing a hundred pounds is of considerably more use in the field than a small cannon, for that with pieces of rock inflicts considerable damage upon the enemy, and the small cannon or rather its ball, being of lead, does not rebound after the first blow by reason of its weight, and on this account it is less useful.

If you set an arrow so that it is just in equilibrium on top of a stone which seems on the point of falling over, you will perceive that a large bombard if discharged at a distance of ten miles from this arrow will cause such a tremor of the ground as to make the said arrow fall, or the stone upon which it is balanced.

Again if you discharge a small bombard in a courtyard surrounded by a convenient wall, any vessel that is there or any windows covered with cloth or linen will all be instantly broken; and even the roofs will be somewhat heaved up and start away from their supports, the walls and ground will shake as though there was a great earthquake, and the webs of the spiders will all fall down, and the small animals will perish, and every body which is near and which is possessed of air will suffer instant damage and some measure of loss.

But this small bombard should be discharged without its shell or if you so desire after the fashion of the curtall;[1] and it will cause women to miscarry and also every animal that is with young, and the chicks will perish in their shells. C.A. 363 v. d

Having to make mounds of earth on the two opposite sides of the river this is the most expeditious manner in which it can be done, provided you have men with hand-barrows:

Allowing six shovelfuls to each hand-barrow, and casting the earth at a great distance:

The diggers *d* enter underneath a shovelful, always drawing themselves back, and the diggers *b* make another second shovelful below, that is deeper down, always going forward; and if there were two other similar lines of diggers these would go beneath the third and fourth shovelful, and so successively they would be able to continue from hand to hand.

[1] MS. *cortaldo*. 'Curtall, a kind of cannon with a comparatively short barrel, in use in the sixteenth and seventeenth centuries.' *Oxford English Dictionary*.

Here many men become fatigued merely by taking loads for so great a distance, so that we have to consider whether it is better that the men should remain in one spot and throw the soil from one to another, or should all be employed in digging and throwing, or whether some should be carriers of this soil and others throwers. For as regards the place where this earth is discharged it requires as much effort for the shovelful of the first or of the second to reach it in one way as in the other: nothing therefore need be considered here except the convenience and endurance of the workers. C.A. 370 r. b

[*With sketch of cannon*]

The mouth one eighth of its diameter thick, and at its union with the tail one quarter of its diameter thick. Tr. 61 a

If you are attacked by night in your quarters or if you fear to be, take care to have mangonels in readiness which can throw iron caltrops; and, if you should be attacked, hurl them in among the enemy and you will gain time to set your men in order against their assailants, the outwitted enemies, who because of the pain caused by the wounds in their feet, will be able to effect little. And the plan of your attack you will make thus:—divide your men into two squadrons and so encircle the enemy; but see to it that you have soles to your shoes and that the horses are shod with iron, as I have said before, since the caltrops will make no distinction between your men and those of the enemy, and see that each mangonel throws a cartload of the said caltrops.

HOW TO PROTECT ONESELF FROM CALTROPS

If you wear between the foot and the sole of the shoe a sole of cloth woven of cords of cotton of the thickness of a finger you will be safe from caltrops, which will not thrust themselves into your feet.

If you wish to be safe from light shifting sand upon the galleys, have heavy river sand strewn upon the gangway and where you have to set your feet; and pitch will fix this, and keep sacks always in readiness for when they may be needed. Tr. 88 a

You should make caltrops of plaster with the arch of iron and the moulds in three parts, and then the points should be filed. [*Below—*

sketches of three caltrops with four points and of one with eight, each of the four being duplicated close together—below this is written 'double caltrop'.]

These caltrops should be kept in a leather bag by the side of each person, so that if the expected victory should be changed to a defeat through the strength of the enemy, the fact of these being scattered behind them would be the cause of checking the speed of the horses and of bringing about the unhoped-for victory.

But lest in retreating this crop should be the cause of a similar mistake for yourselves, you should first have made ready the irons for the horses in the form represented below, and have nailed between the iron and the horse's foot a plate of steel as thick and wide as the above-mentioned horse's iron.

And in the case of foot-soldiers they should have iron plates fastened to the soles of their shoes, not tied tightly, so that they may be able easily to raise their heels and take steps and run when necessary without any restraining obstacle, and the knot that is left loose should be as it is represented here below.

Moreover if you have a small bag of them by the side of each naval combatant and they are then thrown by hand on the enemy's galleys or ships they will be sowing the seed of the approaching victory; but you should have the shoes bound with iron, as was said above, and covered over below with tiny points, in order that if it should come about that soft soap be thrown upon your ship you will be able to keep your feet, even though the enemy should throw chalk in the form of powder in such a dense cloud as to devastate the air which is breathed into the lungs.

You should set up four stations at four positions in the length of the ship, and at each of the four stations let there be a small barrel with a certain quantity of water, and large syringes which serve to force the water out through many small holes, so that the water may become changed into spray and may thus accompany the dust of the chalk and draw it downwards.

[*Three sketches—below*]

syringe; iron sole for shoes; iron for horse for caltrops. Tr. 90 a

[*Drawing of fire-ball*]

This ball as it is thrown becomes extinguished, and as it reaches the ground the canes which are bound at the top with linen cloth that has been set alight are driven into it, thus igniting the powder which is all round a piece of tow that has been soaked in turpentine, the rest of it being wrapped in hemp which also has been soaked in turpentine, oil of flax, and pitch, and the wrappings should be thin in order that the flames may get the air, for otherwise you will do nothing.

4 r.[1]

RHOMPHEA

This *rhomphea* can be drawn with army horses, as the ancients drew other instruments.

This [*small drawing of instrument*] is attached to the centre of a piece of plank, or piece of chain, or stout cord, that is fastened to a lump of stone heavier than the plank and so drawn behind the plank, which on the front edge is full of spontoons of the length of a cubit, and the said plank will be twelve braccia long, and its surface is studded with nails. B 7 r.

SCORPIONS

A scorpion is a machine which can hurl stones, darts and arrows; and if it is made large it will be suitable for breaking the machines of the enemy.

Other authors are of opinion that a scorpion is a poisoned arrow which however little it may touch the blood causes instant death. And it is said that this weapon was found among the Scythians, others say among the inhabitants of Candia. The brew was made of human blood and serpent's venom. This weapon should not be used except against traitors, for it comes from them. B 7 v.

CATAPULT

The catapult according to Nonius and Pliny is an instrument invented by that Ticlete,[2] which threw a dart of three cubits, and with

[1] The notes on instruments of warfare in this manuscript, B of the Institut, are extensively derived from the *De re militari* of Roberto Valturio.

[2] Tiglath Pileser? (Ravaisson-Mollien).

iron on three sides, thrown by means of wood released from the contraction of twisted sinews.

A bit of thin steel also springing back when released will have power to drive a dart swiftly when it stands in its course. B 8 r.

RHOMPHEA

The *rhomphea* is an instrument which throws out long brands of burning wood; it was used among the Thracians according to Aulus Gellius, and by the men of other nations it was called *flammea*.

THE BOW

The bow is said to have been invented by the inhabitants of Arcadia, some say by Apollo; those of Candia call it Scythian as coming from Scythia. And it is much in use among the eastern peoples. They make arrows of canes for these bows, and in their battles there are sometimes so many of them in the air that the day becomes so darkened as to seem like night. So for this reason they have a hatred of the clouds and the rain and the winds no less, because they divert the course of their arrows; and these causes often bring treaties and peace among them. B 8 v.

The spikes (*murici*) or caltrops (*triboli*) are for use on the field of battle, in order to scatter them on the side on which there is reason to expect the assault of the enemy, and also for throwing among the enemy when they follow up their victory.

The *scalpro* was a sharpened iron used to prick and control elephants. Livy in the Seventh Book of the Carthaginian War says that many more elephants were killed by their own governors than by the enemy. For when these beasts got enraged with them the governor with a mighty blow thrust the sharp *scalpro* between the ears where the neck joins the spinal column; and this was the most rapid death that could be given to so huge a beast.

The *veruina* according to what I find in a comedy of Plautus[1] is a long spear with a sharp iron point for hurling.

[1] The reference is to Plautus's *Bacchides,* Act 4, Scene 8, l. 46. Si tibi est machaera, et nobis veruina est domi.

The *soliferreo* is a kind of weapon entirely of iron which the soldiers used to throw at their first assault. Livy mentions it in the fourth book of the Macedonian War.

Fonda (sling) is made of a double cord and is somewhat wide where it is bent, and being weighted with a stone and then turned twice in rapid succession by the arm it releases one of the cords, and the stone flies with a noise through the air as if it proceeded from a catapult. Flavius [1] says that it is found among the inhabitants of the Balearic Isles, that they have supreme skill in the use of it, and that the mothers do not allow their children any other kind of food than what has been brought down by them as a mark with a stone shot from a sling. Pliny on the other hand says that this sling was invented by the Syro-phoenician peoples.

Glande are leaden balls shot with catapults and slings. B 9 r.

Auctori according to Celidonius are sickle-shaped weapons with a cutting edge on one side only and the length of a braccio. They have the handle forked after the fashion of the tail of a swallow. They are not carried in a sheath but bare, attached to the girdle.

Danish are a rather long kind of hatchet: they are said to have been much in use among the Danish peoples. But what has to be taken into account with respect to instruments of warfare made of iron is that that which has been steeped in oil will have a fine edge, and that which has been immersed in water will be rough and brittle. Those which are soaked in the blood of a goat will be the hardest. Oil, white lead and pitch preserve iron from all rust.

Falce (scythe) is of iron, crescent-shaped, and with a staff fastened to one of its horns. This weapon was much in use among the Thracians and in naval combats no less than on land. It was afterwards converted for the use of husbandmen and peasants.

They were used by the Romans upon their ships; unheard of in size and skilfully manipulated by means of ropes they severed the ropes of the lateen yards as though they were razors, and caused the sails to fall at the same time as the yards, so that what ought to have been a help to the enemy was a great hindrance to them.

Fragilicha is a ball half a foot across, filled with small barrels made

[1] Flavius Josephus? (Ravaisson-Mollien).

of paper and crammed with pepper, sulphur and . . . of Corsica (*conocorsico*). And whoever receives the smell of it falls in a swoon; and in the centre of this ball is the powder of a bombard which when kindled sets fire to all the barrels, and when it is first thrown among the troops with a sling the fire catches a wisp of straw, and the sparks proceed to spread over a space of a hundred braccia. B 9 V.

CAR WITH SCYTHES

[*Drawing*]

These cars armed with scythes were of various kinds and often did no less injury to friends than they did to enemies, for the captains of the armies thinking by the use of these to throw confusion into the ranks of the enemy created fear and loss among their own men. Against these cars one should employ bowmen, slingers and hurlers of spears, and throw all manner of darts, spears, stones and bombs, with beating of drums and shouting; and those who are acting thus should be dispersed in order that the scythes do not harm them. And by this means you will spread panic among the horses and they will charge at their own side in frenzy, despite the efforts of their drivers, and so cause great obstruction and loss to their own troops. As a protection against these the Romans were accustomed to scatter iron caltrops, which brought the horses to a standstill and caused them to fall down on the ground from pain, leaving the cars without power of movement. B 10 R.

FOR PASSING A RIVER

You ought when you wish to make the passage of a river with an army to make use of wine-skins attached to the saddle, and, as the horses are not able to swim much on account of the waves leaping up, you should carry an oar fastened to the neck behind so that [the rider] can work it when necessary. B 10 V.

[*With drawings: flammea, pilocrotho, arzilla, crusida, lampade, astula*]

The *flammea* is a ball put together in this manner: Let the following things be boiled together, the ashes of willow, saltpetre, aqua vitæ, sulphur, incense, and melted pitch with camphor, and a skein of

Ethiopian wool which after merely being soaked in this mixture is twisted into the shape of a ball and filled with sharp spikes and thrown on ships with a cord by means of a sling.

This is called Greek fire, and it is a marvellous thing and sets fire to everything under the water. Callimachus the architect was the first to impart it to the Romans, by whom it was afterwards much employed and especially by the Emperor Leo, when the eastern peoples came against Constantinople with an infinite number of ships which were all set on fire by this substance.

Pilocrotho, arzilla, crusida, flammea, lampade, although they differ are nevertheless almost of the same substance, and their fire is similar to that spoken of above, that is of the *flammea* except for the addition to the said composition of liquid varnish, oil of petroleum, turpentine and strong vinegar, and these things are first all squeezed together and then left in the sun to dry, and afterwards twisted about a hempen rope and so reduced to a round shape. Afterwards it is drawn with a cord, and some bury the point of a dart in it, transfixing it after having wetted the dart, some bury very sharp nails within it; and a hole is left in the said ball or mass for the purpose of setting it on fire and all the rest of it is smeared with resin and sulphur. Our forefathers made use of this compound pressed tightly together and bound to the end of a spear, in order to ward off and resist the impetuous fury of the enemy ships.

Lucan says that Caesar used to make this fire in order to throw it by means of lamps upon the ships of the Cerusci, a people of Germany; he burnt not merely the said ships, but the buildings constructed upon the borders of the sea were consumed by a similar fire. B 30 V.

The *folgorea* is a mortar with an opening in its tail circular in form, in the centre of which occurs a thin *chanicula* [chamber?] of iron finely perforated, with the hollow of it filled with fine powder; and it is made thus for two reasons, first, that when it reaches the centre of this ball, the fire, which passes through the chamber, lights in an instant all the rest of the powder that finds itself pressed within this ball, secondly, so that the hole of the mortar may not become worn. And this round opening will not resist the might of the powder unless it is made of fine copper, but the rest may be made with four parts tin to every hundred of copper, and this is the best machine that it is possible to make. B 31 r.

The *clotonbrot* is a ball thrown by a *trabiculo*, that is a lesser mangonel which is a braccio high and filled with the ends of cartridges packed all together in a tiny space. It is used for throwing into a bastion and there is no remedy that avails against its pestilential effect, but for this purpose its use would be a mistake because it does damage to you as well as to the enemy. And if you throw six or eight of these balls among the enemy you will certainly be the victor, so it is good to throw it in the midst of them, and light the fuse within which will at last set fire to the centre of all the sticks.

This is for ships.

When the ships are engaged, have fuses to keep the enemy back, and at that moment throw balls full of lighted fuses among the enemy, that is to say upon the ships, and the enemy being occupied in protecting themselves from the fire will abandon their defences. B 31 v.

[*With drawing of two cannon placed vertically with stand between them*]

Whoever wishes to make trial which is the better must raise them on end and two judges should be in the centre, and after first firing the one it must be noted how much time there is from the explosion to the return of the ball to the ground and then the same is done with the other and the one which takes longer will have the honour.

But see that the tubes are of equal length, that the touch-holes work freely, that the balls are of the same weight, and the powder is from the same keg. B 32 r.

[*With drawing*]

If you wish to be able to ford a river with your army when you please you will proceed as follows:—make a boat of osiers of willow and make it with the brims double in such a way that they open from below, and fill the body of it with gravel. And when you are at the place that you wish, open the store of gravel from below so as to cause it to fall to the bottom; after doing this close the receptacle and return to the bank to reload. You will need to have a number of these machines, but the actual body of the boat should be bound outside with oxhide to prevent it falling to the bottom.

[*With drawing*]

To make an airgun which shoots with marvellous force you should proceed as follows:—stretch a steel wire the width of a finger on a wire-drawing machine by means of a windlass; then temper it, and beat round about it two plates of fine copper which you stretch on the wire-drawing machine. Then half to half solder them together with silver, wind thick copper wire about it and then smooth it with a hammer, but first solder it. And do this three or four times in the same way. And make [the airgun] two braccia long and make it so that it can shoot a dart of a third of a braccio which is of steel. B 32 V.

The *architronito* is a machine of fine copper, an invention of Archimedes, and it throws iron balls with a great noise and fury. It is used in this manner:—the third part of the instrument stands within a great quantity of burning coals and when it has been thoroughly heated by these it tightens the screw *d* which is above the cistern of water *a b c*; and as the screw above becomes tightened it will cause that below to become loosened. And when consequently the water has fallen out it will descend into the heated part of the machine, and there it will instantly become changed into so much steam that it will seem marvellous, and especially when one sees its fury and hears its roar. This machine has driven a ball weighing one talent six stadia.

B 33 R.

[*Fire-ball*] [*With drawing*]

This ball should be made of melted pitch, sulphur and tow of hemp rubbed together so that when it burns the enemy may not carry off the invention.

This ball should be two and a half braccia in height and filled with tubes which can throw a pound of balls, and these should be coated with pitch within the tubes so that they do not fall.

The tubes should be a braccio in length, and made of pasteboard after the manner of spokes, and the space between them should be filled with plaster and wadding; and the ball should be thrown upon the bastions by means of a mangonel.

The centre of it will be a cannon-ball to which the tubes serve as good epaulets, or a hollow ball of bronze which may be partly filled with powder, with its circumference perforated so that the fire is able to penetrate to the tubes; and the ball should be all tied up on the outside except for a hole to serve as a passage for the fire. B 37 r.

[*With drawings*]

Cortalds (short pieces of artillery) are good against big ships.

The serpentine (*passavolante*) is useful for light galleys in order to be able to attack the enemy at a distance. It can throw four pounds of lead and ought to be as long as forty cannon balls.

This spontoon will fasten the instrument into the ship if the blow is great.

This *zepata* is good for setting fire to ships which have kept a blockade after having besieged some harbour or other ships in the harbour, and it should be made thus: first wood a braccio above the water, then tow, then powder as used for a bombard, then tiny faggots and so gradually larger ones; and put iron wires and burning rags on the top; and when you have the wind as you want it direct the rudder. And as the fire *m* spreads in the ship the bent wires will set fire to the powder, and it will do what is necessary.

It is also useful for setting fire to bridges at night, but make its sail black. B 39 V.

NAMES OF WEAPONS

Acinace. *Acinace* is the name of this knife: it was so called among the Scythians and Medes, according to the statement of Acro.

Daga. This among the Ligurians was called daga.

Ensis. *Gladius*. *Ensis* and *gladius* are a kind of weapon, and, according to Quintilian in the tenth book of his Institutions, they are the same thing.

According to Pliny in the sixth book of Natural History, the *gladius* was invented by the Lacedaemonians.

According to Varro, when the *gaesum* (javelin) became obsolete the *gladius* was used in its place. It has been called *aclis* because it was used for the destruction and death of the enemy.

Spada, *ensis*, and *gladius* are names of arms universally known and especially among the ancients.

Arpa. Arpa, according to Lucan in the ninth [book], is said to be a sword of the shape of a sickle with which Perseus slew the Gorgon.

The bows were called *manubaleste*. B 41 r.

Lingula, according to what Naevius says in one of his tragedies called *Ceisonia*, was the name of a small knife of the shape of a bird's tongue.

Machaera is a kind of long weapon with one part of it sharpened. Caesar mentions it in the second of his Commentaries.

Stragula is a kind of lance for throwing and for using with the hand. Caesar mentions this also in the second of his Commentaries.

Doloni are a kind of weapon mentioned by Plutarch in the life of Gracchus.

Others are of the opinion that *doloni* are whips with daggers concealed in their handles.

Sica is a small knife used by *assassins* in ancient times, who were called *sicarii* from the name of the knife according to Quintilian in the ninth book of the Institutions.[1] B 41 v.

Pugio, according to Pompeius Festus, is a short double-pointed knife.

Varro says that *pugio* is the name given to a long lance with iron.

Clunade (*clunaculum*) is a sacrificial knife.

Secespita is a long knife with a round handle made of a piece of ivory and ornamented with gold and silver. It is used by the high priests and the flamens for the sacrifices.

Some say it is the axe (*scura*) and some that its edge resembles that of the manara.

Mucro is identical with *ensis* and *gladius*, according to Priscian in the second book of the Ars Grammatica.

Aclides, according to the opinion of Servius, are a kind of weapon so ancient as to have been entirely overlooked in war. Nevertheless we read that they were pieces of wood, some half a cubit in length and some circular; and in them were fixed iron points which were sharp and projected; and they were hurled among the enemy with a cord or leathern thongs, and he who received the blow soon knew who had given it. B 42 r.

[1] cf. 'per abusionem sicarios etiam omnes vocamus, qui caedem telo quocumque commiserint.' Quint. 10, 1, 12.

Telo (*telum*) was the word generally applied by the ancients to all those things which in war were suitable to be thrown with the hands, such as darts, clubs, arrows, spears, lances, stakes and stones.

Veruto. The *veruto* (*verutum*) (javelin), according to Nonius Marcellus, is a small weapon and very straight.

Fusti. Fusti (*fustis*) (club) were the first weapons that the human race used, and they are today called stakes by countryfolk; and their points were somewhat charred.

Baculo. The *baculo* (*baculum*) is a stick without a hook to it with which unhappy slaves were beaten.

Haste (*hasta*) (spear) is said to have been invented by the Lacedaemonians. They are excellent and . . .? (*plestante*) when made of ash or hazel, but better still when made from the service tree, because this is more supple and flexible.

Astili are the smaller lances which are thrown deftly with the hands.

Cuncti (*conti*) are very long and stout pikes without iron but having their point sharpened. Lucan makes mention of them.

Lancea. Pliny says of the lance that it was invented by the Aetolians. Varro says that *lancia* is a Spanish word. B 42 V.

Pilo (*pilum*) was a spear in use among the Romans, resembling the *gaesum* of the Gauls and the *sarissa* of the Macedonians. And these spears were divided in their length in two equal parts and the heads were placed at each end. They were joined together with fish glue and at every half cubit bound with gut. Writers say that these spears were so perfect that if they were suspended by a cord in the form of a balance they did not bend. And if one first draws it back and then drives it forward with fury there is no armour of sufficient strength to resist it. They were much in use among the Bretons.

Giese (*gaesum*) is a weapon used by the people of Gaul, and they are no less useful for hurling than for use in any other way.

Ruma, *pilum*, *rumex* and *telum* resemble each other and resemble also the sparus of the Gauls.

Jaculo (javelin) is said to have been invented by Ætolus the son of Mars, and to this Hermes, Varro, Pompeius Festus bear witness, affirming that javelins are rude and fashioned by rustics of poor mean condition but suitable for scattering on all sides. B 43 r.

Sarissa. Sarissa, according to Pompeius [Festus], is a Macedonian spear.

Gabina. Gabina is the name given by the Illyrians to a certain kind of weapon of the shape of a hunting-spear (*venabulum*) or pike.

Securis (battle-axe) is called also *semicuris* or *semiquiris*.

Tragula. Tragula is a spear with a very sharp point of the shape of a javelin or dart which can be thrown by the hand according to Varro, Pompeius, and Caesar in the fifth of the Commentaries.

Clava. Clava [club] is a kind of weapon which was used by Hercules, and it was so called because it was a big strong stick studded with sharp nails, and this in these rude times would be considered a very magnificent weapon.

Cathegia. [Boomerang?] Some believe this clava to have been the *cathegia* which Horace calls *caia* and that the *cathegia* was a kind of dart in use among the Gauls which comes back at the wish of the thrower. According to Virgil it was greatly in use among the Germans; the knights made a great use of it against the infantry. B 43 v.

Dolabra, that is, double-cutting.

It is called two lips (*labbri*) after what Livy states in the eleventh book [1] of the Punic War, where he relates that Hannibal sent five hundred Africans armed with these in order to lay waste to their foundations the walls of a town.

Bipenna. This weapon is so called because it has a sharp edge on both sides. The term is usually applied to it by Quintilian, in the first book of the Institutions. B 44 r.

The cross was invented among the Germans, and this weapon is said to be in the front rank of deadly weapons, seeing that if it is thrown either with a cord or without among the ranks of the enemy it never falls there in vain. And this because it runs edgewise through the air and if it does not catch the enemy with one of its points it catches him with two, or not finding the enemy there it is driven into the ground, where it inflicts no less damage upon the enemy than if it

[1] As M. Ravaisson-Mollien has stated, the passage referred to is in Book XXI, para. xi, but as however Books XI to XX have been lost, Book XXI follows X. '. . . tum Hannibal occasionem ratus, quingentos ferme Afros cum dolabris ad subruendum ab imo murum mittit.'

struck the horses and the footsoldiers. From four to six of these are carried round the belt when one goes into the combat.

[*Drawing of caltrops with cord and thong*]

This method was much in use among the Jews and the neighboring peoples of Syria. And they throw them with cords and long thongs among the enemy on finding themselves vanquished and routed by them; whereby they being thrown down are made to cease their course.

And they also sow them upon their own line.

Telico. These were in use among the first men; and they were made of cane, that is to say that having taken a piece of cane with two knots they split one through the middle and used it as the feather of the arrow; and the other they made into a point and filled it with earth so as to weight it, and they threw these by means of a cord. B 44 v.

Scourge (*flagellum*). This also was among the number of the primitive and rustic arms.

Scythian arrow. The arrow is a simple weapon which was much in use among the Arabs. It was invented by the Scythians, and consists of a piece of green wood of which the end has been burnt; and it may be thrown either by means of a cord or without. If it is held it may be used also as a javelin.

Ganci, *ruffili* and *roncili* are maritime weapons in use among pirates. By means of hooks they are accustomed to grapple the edges of ships, and if any of the ship's defenders should approach them they wound them and drive them before them, and then return to the edges where they were before and dig them deep into the ships so that they cannot escape. B 45 r.

Sirile is a very long spear; it was found among the Numidians. They often used it in order to throw down their enemies, and they rode on horseback without saddle or stirrup, armed only with a doublet stuffed with cotton over which were fastened the hooks of the long sirile; and [the enemy] taken by surprise were easily thrown down.

Cariffe is a broad spear with which one can attack from afar. And if it should come about that the combustible ball should be captured, the soldier can start it by striking it with the sharp iron point that is at the head of the spear, and thus recovering it would scourge the wretched soldiers [of the enemy].

Miricide is a spear three braccia in length, and five braccia and a half when extended: the soldiers use it in the way in which rustics thresh corn.

Malcoli, according to Ammianus Marcellinus, are a kind of dart or arrow. The stem is of cane and where the cane ends a distaff is joined like that used for spinning, and on this distaff the iron is fixed. Tow steeped in pitch should be placed in the hollow of the said distaff, and it should be set fire to and thrown gently so that the rush of the air may not extinguish it. Some say that within this cavity there should be an inexhaustible store which should consist of resin, sulphur, and saltpetre which should have been liquified with oil of laurel, or some say petroleum oil [1] and fat of duck, and marrow of meat, and fennel, and sulphur, resin and camphor with . . . [rasa?] and tow. This mixture among the ancients was called combustible, that is something suitable to burn, also tow, fat, and petroleum. B 45 V.

The *Manara* was much in use among the Romans.

Irish and English bows. But the Irish in place of one corner of the bow have a piece of sharpened iron of the length of a cubit.

The English and the Irish are almost the same length, that is four braccia each.

Syrian bow, made of horns of buffalo.

German bow, made of two pieces of steel and how they are set.

The dart of the cross-bow works in this manner: namely, when the arrow issues forth from the cord and passes over the roller, the ring at the extremity of the arrow causes it to leap back after it has struck; but the iron continues and performs its function.

The dart of the bow by which the arrow remains attached to the cord is an awl a quarter of a braccio in length, all of iron finely tempered; the feathers of the tail come away from the arrow as it flies on its way. Some there are which make a prick resembling that of a needle full of poison. B 46 r.

[*Drawing—soldier on horseback galloping*]

This is a mounted carabineer which is an extremely useful inven-

[1] MS. *olio petrolio.*

tion. The said carabineers should be provided with pouches full of rolls of plain paper filled with powder, so that by frequently inserting them they subdue the excessive numbers of the enemy. And these carabineers should stand in squadrons as do cross-bowmen, so that when one part fires the other loads; but first make sure that you have accustomed the horses to such noises; or else stop up their ears.

Order of mounted cross-bowmen on the open field: *m n* are cross-bowmen who as they turn left draw back loading, *r t* are those who go forward with cross-bows loaded, and these four files are for one route; *a b* are four files of cross-bowmen who turn with bows unloaded in order to load them anew; *c d* are those who come upon the enemy with their bows loaded; and this arrangement of eight lines is employed in open field.

And have it so that those who have unloaded come through the centre, so that if sometimes they have been routed by the enemy the cross-bowmen who are loaded, holding themselves on the flanks, may cause greater fear to these same enemies.

Order of mounted carabineers:

See that they are well supplied with guns with a thin single fold of paper filled with powder with the ball within, so that they have only to put it in and set alight. Being thus ready they will have no need to turn as have the cross-bowmen when they are preparing to load. B 46 v.

If anyone had formed the design of capturing a tower situated on the sea, he would cause one of his followers to take service with the commander, and when the guard was withdrawn he would affix to the battlements the rope-ladder given him by the enemy and would fill the walls with soldiers. In order to prevent this, you should divide the tower into eight sets of staircases, spiral in shape, and divide into eight parts the ramparts and the soldiers' dwellings below; then, if one of the mercenaries should be disposed to be a traitor, the others cannot hold communications with him, and the section of the rampart will be so small that there will not be able to be more than four there. The commander, whose quarters are above those of all the others, can drive them out by attacking them from the machicolations, or shut them up by means of the portcullis and then put smoke at the entrance to the spiral staircases. On no account is it necessary that any alien soldier should lodge with the commander, but only his own family.

B 48 r.

The confederate of the scaler of the wall should carry with him a ball of strong thread when he takes service with the commander, and when the opportunity comes the guard will draw up with this thread a coil of strong twine which has been given him by the scaler, and then with the twine he may draw up the rope which will afterwards be useful for drawing up the rope-ladder as shown above. B 50 r.

NAMES OF ENGINEERS

Callias of Rhodes.[1] Epimachus the Athenian.[2] Diogenes, philosopher, of Rhodes.[3] Calcedonius of Thrace. Febar of Tyre.[4] Callimachus, architect, master of fire.[5]

Fireball worked up:—take tow smeared with pitch and turpentine and linseed oil and twist it round about in such a way as to make a ball; and over it place hemp soaked in turpentine of the second distilling. And when you have made the ball make four or six holes in it as large as the thickness of your arm, and fill these with fine hemp soaked in turpentine of the second distilling and powder for the bombard; then place the ball in the bombard.

[*An arrow of fire*] [*Drawing*]

This is a dart to be shot by a great cross-bow laid flat, and the two

[1] Greek architect, of Arados. Built a great crane for the Rhodians which was intended to hook up and raise in the air the battering engine (ἑλέπολις) used by assailants. (Vitruvius X, 16, 5.)

[2] Architect employed by Demetrius Poliorcetes to construct a battering engine so large that the machines of Callias were useless against it. (Vitruvius X, 16, 4.)

[3] (Diognetus—Ravaisson-Mollien.) Identical perhaps with Diognetes who according to Plutarch (Life of Demetrius) on being appealed to by the Rhodians in this emergency constructed subterranean trenches in which the ἑλέπολις of Epimachus became embedded, thus forcing Demetrius to raise the siege.

[4] See B 51 r.

[5] Sculptor, painter, architect. Famous for his bronze casts (Pliny XXXIV, 8, 19). Inventor according to Vitruvius (IV, 1, 19) of the Corinthian capital; according to Pausanias (I, 26, 7) of a method of boring marble and a lamp of gold which used to burn day and night before the statue of Athene in the temple of Athene in the Acropolis, the wick being formed of some kind of asbestos that was never consumed. It is to this invention that the words 'master of fire' have reference.

corners have the things which produce fire bound in linen cloth; and as the point buries itself the corners are pressed closer together and set fire to the powder and the tow that is soaked in pitch. This weapon is good for use against ships and wooden bastions and other similar constructions; and no one will make good work in this business of burning unless the fire is kindled only after the dart has struck, because, if you should wish to light the fire before, the violence of the wind will extinguish it on its way. B 50 V.

[*With drawings*]

A method of warding off the battering-ram with a bale of straw soaked in vinegar.

A method of intercepting the stroke of a battering-ram.

Heliopolim, a mural machine (battering-ram).

Cetra, a mural machine (battering-ram).

Febar of Tyre made use of this instrument in order to shatter the walls of Gades.

Flemisclot, a mural machine (battering-ram).

In order to make green fire take verdigris and soak it in oil of turpentine and pass it through the filter.

A way to make a cart on rollers which run upon a board or floor or hard ground: and this is for use to move heavy weights for a short distance. B 51 r.

This bombard ought to be somewhat wider at the mouth in order that the stones as they come out of it may scatter, and one ought to take a shell[?] (*cocone*) formed of the root of an oak in order to have a half ball for the bombard, and this will have a good effect in desperate cases. B 54 r

[*With drawing*]

Of the way in which when the battle is begun by scaling the walls one may draw beams up above the top of the battlements, and then by giving them a push cause them to fall upon the ladders and the assailants; and the method of drawing the said beams rapidly should be made use of in the manner shown here. B 55 r.

[*With drawing*]

To show how with a mangonel one can throw a great quantity of burning wood upon ships together with pitch, or if you wish with stones or even with powder from a mortar, mixed with straw and vinegar.

Let these pieces of wood be bound and interwoven with fine iron wire fastened together with a chain. B 55 v.

[*With drawing*]

How one ought to defend oneself against a furious attack by soldiers who are attacking a hill fort. Namely by taking barrels and filling them with earth and rolling them down the slope upon the enemy, for these will be of great benefit to those who have despatched them. B 56 r.

[*With drawings*]

This shield should be made of fig-wood inside, with cotton of the thickness of a quarter of a braccio outside it, and outside the cotton it will be well to put fustian with a coat of varnish; or if you make the outside of cotton and the inside of isinglass and tragacanth and varnished, with half the amount of cotton, plain and compressed, with nails going from one surface to another, it will be satisfactory, and you can dry it in a press.

These balls should be filled with small dust of sulphur which will cause people to become stupefied.

This is the most deadly machine that exists: when the ball in the centre drops it sets fire to the edges of the other balls, and the ball in the centre bursts and scatters the others which catch fire in such time as is needed to say an Ave Maria, and there is a shell outside which covers everything.

The rockets of these balls should be made of paper, and the space between each filled with plaster ready to be moulded, mingled with the clippings of cloths. And they should be set alight with a pair of bellows which will cause the flame to extend to the centre of the ball among the powder, which separates at a considerable interval from each other all the balls filled with rockets.

Wheel full of tubes of carbines for foot-soldiers. B 59 r.

HOW TO SCALE A FORTRESS BY NIGHT

[*With drawings*]

If you have not any information from within as to who will draw up the rope-ladders, you will ascend first by placing these irons in the crevices a braccio's space apart in the manner shown above.

And when you are at the top, fix the rope-ladder where you see here the iron *m*; let it be bound with tow so that you do not make any sound and there remain. Then if it should seem that you ought to draw up other ladders, do so; if not, cause the assailants to ascend quickly. The hook which is attached to a brace of ropes has above it a ring to which is fixed a rope, and this is drawn up by a jack to the iron above, and to this you attach a second time the hook of the above-mentioned braces.

These ladders are made to carry two men. They are also useful for a tower where you are afraid lest the rope-ladder may be detached by the enemy; they should be driven so far into the wall that three eighths [of a braccio] is buried and one eighth is free. These pyramidal irons should be half a braccio in length and their distance apart half a braccio. B 59 V.

[*With drawings*]

SACKS FOR USE IN CROSSING OVER WATER

It is also necessary to reflect how one ought at one's convenience to make the passage of rivers. First set a man upon two bags bound together, then if you find the bottom to be suitable and that the river is dangerous through the rapidity of its course make use of the method represented below.

If the river is dangerous by reason of its current you should set two lines of horses across the river at a distance of six braccia one from the other, and the horses in the lines should be so near as almost to touch each other, and the line or company of horses should have their heads turned towards the current of the water, and this is done solely in order to check and break the fury and impetus of the water. And between the one company and the other pass the soldiers both those with and those without arms. The company that is higher up the stream should be made up of the bigger horses in order to be better able to stem the rush of the river, that lower down serves to hold up the soldiers when they fall, and to act as a support for them as they make the passage.

B 60 V.

[*With drawing*]

Make shelters by interlocking shields to withstand the fury of masses of arrows.

The method in which the Germans when in close order link together and interweave their long lances against the enemy, stooping down and putting one of the ends on the ground and holding the other part in their hands.

[*With drawings*]

If the water is so high that infantry and cavalry cannot pass, the river should be diminished by leading off many streams, as Cyrus, King of the Persians, did at the taking of Babylon upon the river Ganges [*sic*] which at its maximum breadth is ten thousand braccia, Alexander likewise upon the same river, Caesar upon the river Sicoris.

If it should come to pass that the river was so deep that one could not cross it by fording, the captain ought to make a sufficient number of streams to carry off the water and afterwards give it back below to the river, and in this way the river would come to be lowered and could be crossed with ease. Alexander employed this method in India against King Porus at the passage of the river Hydaspes, and Caesar did the same in Gaul (and also in Spain) upon the river Loire; having arranged his cavalry in two companies he caused the soldiers to pass through the middle of them. Hannibal did the same on the Po with elephants. B 61 R.

[*With drawings*]

The Egyptians, the Ethiopians and the Arabs in crossing the Nile are accustomed to fasten bags or wine-skins to the sides of the forequarters of the camels in the manner shown below.

In these four rings in the net the baggage-camels put their feet.

The Assyrians and the inhabitants of Euboea accustom their horses to carry sacks in order to be able at will to fill them with air. They carry them instead of saddle-bows above and at the side and well covered with plates of dressed leather, so that a quantity of arrows will not penetrate them, since they are no less concerned about a safe means of escape than the hazard of victory. Thus equipped a horse enables four or five men to cross at need. B 61 V.

[*How infantry cross rivers*]

If it should come to pass that infantry have to pass a river which is dangerous by reason of the force of its current, this is a sure way:—let the soldiers join arms one with another and form themselves into a line after the manner of a stockade, linked together by their arms; and let these files advance along the line of the water and let no one go across its course, and this is a sure way because the first being above the water is the one who sustains its first onset, and if he was alone the water would throw him down, but all the others below him hold him up and use him as their shield; and so by this means one after another they cross in safety. So it is with all: and if the fall of the river is from right to left each man in the file as he proceeds from the first to the second bank ruffles the course of the stream with his right shoulder, and on his left he has the right shoulder of his companion and the flowing water. B 62 R.

NAVICULA

[*With drawings*]

The small boats in use among the Assyrians were made of thin branches of willow, plaited over rods also of willow, arranged in the shape of a small boat, plastered over with fine dust soaked in oil or turpentine and so reduced to a state of mud; this was impervious to water and was not cleft asunder by blows because it always remained supple.

Caesar covered this kind of small boat with oxhide when crossing the Sicoris, a river of Spain, according to the testimony of Lucan.[1]

[*With drawing*]

The Spaniards, the Scythians and the Arabs, when they wish to con-

[1] The reference is to Lucan's *Pharsalia* IV, 130, etc.

Utque habuit ripas Sicoris camposque reliquit,
Primum cana salix madefacto vimine parvam
Texitur in puppim, caesoque inducta iuvenco
Vectoris patiens tumidum superenatat amnem.

struct a bridge very quickly, bind the hurdles formed out of willow upon bags or wine-skins of oxhide, and so cross in safety. B 62 V.

The Germans, in order to asphyxiate a garrison, use the smoke of feathers, sulphur and realgar, and they make the fumes last seven and eight hours.

The chaff of corn also makes fumes which are thick and lasting, as does also dry dung; but cause it to be mixed with *sanza*, that is with the pulp of crushed olives, or, if you prefer it, with the dregs of the oil.

B 63 V.

[*With drawing*]

How to discharge a torrent of water on the back of an army and the bridges and walls of a town.

If you wish to submerge a battlefield or to break through walls without the use of cannon and have the use of a river, do as is represented above. That is you set piles as high as the bank of the river and put them half a braccio apart or farther if you have wider planks; then set these planks between each of the piles and so fill up [the spaces]. When these are filled up raise the connecting rod *M*, then *a* the upper part of the plank will go forward and *b* the lower part of the plank will go back. In this way the parts of the said plank will be edgewise and the water will be free to escape. And make the sluices all to open at the blow of a carbine or other signal so that they may all open at the same time, in order that the flow of the water upon the object which opposes it may be driven by a greater blow and a more impetuous force. And if the river have a steep descent make one of these every half mile, and let each of the panels open by means of a rope to insure them working together, and in order that he who unlocks them may be in safety.

B 64 R.

[*With drawing*]

A METHOD OF CONSTRUCTING A BASTION [AT NIGHT]

If you should be making a bastion at night and have need of light, place these lights inside lanterns and raise them up on the top of long poles, in order that the enemy by firing at the lights may not touch the sappers. And the lights should be of oil so that they may last some time, and the lanterns should be balanced in lamp-stands in this way [*draw-*

ing in text] so that they do not upset when they are raised. And remember that the poles must be painted black and only erected at sunset, so that the light is scarcely visible and the raising of it up is hardly seen by the enemy. And it should be done as noiselessly as possible, and there should be one overseer with a staff for every five sappers, so that the work may be rapid. B 70 r.

In what way one may storm a bastion which has been made in order to close a passage.

Make portable sections of bastions for a furious attack by the men; these should be filled with hay and they should be pointed in front in order that the blows of the artillery may do no damage, and joined together so as to make the bastion of such a size as to engage all the mouths of the artillery and the discharge from the bridges, they will be able to engage the enemy with advantage. B 75 v.

[*How to attack a fortress by subterranean galleries*] [*With drawings*]

Rod filled with rockets for encountering the enemy at the outlet of a subterranean gallery [that opens] from below upwards, which will clear the ground of the men within the entrance.

Rod with rockets for placing in a gallery that leads into a cellar which would be in a fortress and would be well guarded.

m a b. The way of a winding gallery that will deceive the enemy when besieged.

We can clearly understand that all those who find themselves besieged, employ all those methods which are likely to lead to the discovery of the secret stratagems of the besieger. You therefore who seek by subterranean ways to accomplish your desire, reflect well how your enemy will be on the alert, and how if you should make a gallery on one side he will make a trench up to your [gallery], and this will be well guarded by day and by night, for it will be supposed that the secret way as is natural, has its outlet in the said gallery.

When therefore by your digging operations you show that you wish to come out in one particular spot, and by making the circuit of the fortress you come out at the opposite side, as it is shown above in *m b a*, *b* will be when you are almost at the outlet in a cellar that is *a*. You will have a great reserve of men who on the breaking of the wall that is between you and the cellar . . .

When you have made your gallery almost to its end and it is near to a cellar, break through suddenly and then thrust this [rod] in front of you filled with rockets if you find defenders there, but if not do not set fire to them lest you make a noise. B 78 r.

[*With drawings*]

Stlocladle. Place in the centre powder formed of dried fungi.

These balls filled with rockets are to be thrown within the bastions of the enemy.

The *stlocladle* is a ball a foot wide which is made up of hemp and fish-glue and is covered with the tails of rockets, and these tails do not exceed in length the length of a finger, and each tail is of fine copper veined or of sized pasteboard, and all the said tails have their extremities pierced by a tiny hole, and they are all attached to a copper ball which is full of many paths after the manner of a labyrinth, filled with powder; and the said paths are full of holes that cross them which meet with the holes of the rockets.

Then one sets fire to it by means of a bellows and the fire hurls itself through eight holes so that no one can control it or . . . [*ariegi?*], and when the fire has penetrated to the centre the rockets begin suddenly one after another with a dreadful din to spit forth their deadly missiles. If you wish to make use of it on a galley make the rockets of pasteboard, and fill the space between each with pitch mixed with powdered sulphur; and this will serve three purposes: first it will do harm with the rockets, second it will kindle a fire there which cannot be put out, and will burn the wood, and (third) no one will be able to approach it because of the great stench.

Buffonico. The *buffonico* is an instrument set at the end of a lance. It is two braccia long and an eighth of a braccio thick. It is shod with iron and has a thin tube with the sight placed on the extremity through which it passes to the fire.

First of all fill the cannon with the powder well crammed, pressed, and beaten through the mouth *a b*, then make a small hole an eighth of a braccio long and insert a small tube with a very fine hole. The powder should be fine and mixed with dust of lead made with a file or by fire; and it will cause great terror and loss to the horses and to the enemy. B 80 v.

Vinea. The *vinea* is a machine which makes the road and levels the embankments. B 82 v.

[*With drawing of tank*]

These take the place of the elephants. One may tilt with them. One may hold bellows in them to spread terror among the horses of the enemy, and one may put carabineers in them to break up every company. B 83 v.

THAT MURAL ENGINE WHICH MAKES THE LOUDER NOISE HAS THE LESS FORCE

This is proved by the ninth, 'Concerning Percussion', which says: of things movable, in proportion to the power of the mover and the resistance of the medium, that which in like movement strikes with a larger part of itself will make a louder noise and a less violent impact; and that on the other hand which strikes with a less part of itself will make a less noise and penetrate farther into the place where it has struck. An example has been cited of a sword striking first with the flat and then with the edge, for in the one case the stroke makes a great noise and penetrates a very little way and in the other it penetrates a long way and makes but little noise. As the flame therefore is in proportion to the projectiles driven by the pieces of ordnance which are thus in the medium proportioned to them, that flame which separates least after emerging from the piece of ordnance will be that which will drive the ball out with most impetus, and the flame that separates rapidly will do the contrary.

OF PIECES OF ORDNANCE THAT HURL MANY BALLS AT ONE DISCHARGE

A piece of ordnance which throws a ball a distance proportionate to its force, will in the same time throw six of the same balls a sixth part of the aforesaid distance. E 27 v.

OF PIECES OF ARTILLERY AND THE WEIGHTS OF PROJECTILES PROPORTIONATE TO THEIR FORCE

Of the chambers or receptacles for powder of pieces of artillery one finds three varieties of shapes; of which one is wide at the bottom and narrow at the mouth; another narrow at the bottom and wide at the mouth; the third is of uniform width.

There are four [?five] places at which one sets fire to pieces of artillery. Of these one is the extreme upper part of the bottom of the chamber; another is at the middle of the bottom of this chamber; the third is as far removed from the bottom of this chamber as half the diameter of the circle of this bottom; the fourth receives the fire in the same position as the third but in the centre of the thickness of the powder; in the fifth the chamber is round and the fire is set in the centre of the chamber. But this instrument and the others which set the powder alight in very quick time ought to be of fine substance and well compressed. This compression occurs very rarely when the cast is of great thickness, because in the case of these the metal remains liquid longer in proportion as they are thicker, and because the parts of it which are most distant from the centre of this thickness are those which are compressed first. E 28 r.

[*Ancient military terms*]

Chiliarch = captain of thousand
Prefects = captains
Legion = six thousand and sixty three men. H 95 [47] v.

[*Of the trajectory of a bombard*]

If a bombard hits a mark in a straight line at ten braccia how far will it fire at its greatest distance?

And so conversely if it fires three miles at its greatest distance how far will it carry in a straight line?

If a bombard fires at different distances with different curves of movement, I ask in what section of its course will the curve attain its greatest height. I 128 [80] v.

[*Bombards*]

If with its maximum power a bombard throws a ball of a hundred pounds three miles, how far will it throw one of two hundred or three hundred or any other weight more or less than a hundred?

If a bombard with four pounds of powder throws a ball weighing four pounds two miles with its maximum power, by how much ought I to increase the powder for it to carry four miles?

If with four pounds of powder a bombard hurls a ball of four pounds two miles how far will six pounds of powder hurl it? I 130 [82] r.

Of the movement of the cannon-balls of bombards, and of the nature of the stock and breech of these bombards.

Whether the ball moved by force will have a greater movement than that which is moved with ease or no.

Whether if a bombard can throw a ball of a hundred pounds it is better to put two balls of fifty pounds for one and make the stock narrow, or rather with the stock wide to throw one ball of a hundred pounds.

If the bombard can throw two or three balls with ease I ask whether it is better to make the ball long or no.

If a bombard throws a weight of a hundred pounds a distance of a mile, how far will it throw a hundred balls of one pound at one discharge?

Whether it is better for the bombard to be narrow at the mouth and wide at the foot, or narrow at the foot and wide at the mouth.

I 133 [85] v.

If the bombard rests on the ground or a stump, or straw or feathers, what difference will there be in the recoil?

If two bombards can be fired in opposite directions if the breach of the one be placed against that of the other in a straight line.

If the bombard is fired at sea or on the land what difference there will be in its power.

What difference there is between the movements made upwards or crosswise, or in damp or dry weather, or when it is windy or rainy or with snow falling, either against or across or in the direction of the course of the ball?

Where the ball makes most rebounds—upon stones, earth or water.

How the smooth ball is swifter than the rough one.

Whether the ball revolves in the air or no.

Of the nature of the places struck by these balls. I 134 [86] r.

For a bastion to have spring in it, it should have a layer of fresh willow branches placed in the soil at intervals of half a braccio.

K 93 [13] r.

[*Powder for a bomb-ketch*]

One pound of charcoal
eleven ounces of sulphur
five pounds of saltpetre.

And mix it well and moisten it with good brandy, and dry it in the sun or at the fire. Then pound it until one cannot see a speck of sulphur or saltpetre but it is all black and uniform and fine, and moisten it again with the brandy and keep it so. Dry it in the sun in grains and crush just so much as can be placed upon the hole, and this will be sufficient. L 4 V.

[*For digging trenches*]
[*With plan*]

At this commencement of the excavations of the trenches you have to place men according to the marks shown. And first of all make the excavation as far as possible from the place where the earth is tossed. For example, the earth is excavated at *a g*, it is carried along the line *r c*, unloaded by the line *c f*, and then the man turns back along the line *f d* and loads by the line *r d*, being always in movement.

There is no other movement here as useful as that which removes the soil from the place where the line *r c* is marked. L 24 r.

[*Fortifications*]

The wall fifteen feet thick at the base and thirteen above.

The trench forty two braccia wide at the bottom, fifty at its mouth; twenty braccia in height, with water four braccia deep. L 29 r.

Fifteen steps and a span from the battlements to the water, that is from the beginning of the battlements, and these steps are the distance from one extremity of the palms of the hands to the other, opening them as far as one can upon a rectilineal measure. And there are eight braccia and a sixth from the said beginning of the battlements to the summit of the turret. L 67 v.

[*Of digging a trench*]

Width of trench and its depth. Diameter of wheel and thickness of beam and cord. And position of men who turn it and number of men who work this wheel. How many there are in position and what weight they draw at one time, and how much time is required to fill and move in order to empty and turn, and similarly how many shovelfuls one man digs out in an hour, and what a shovelful weighs, and how far he throws it away from himself either upwards, across or downwards, beyond the hillock. L cover r.

Which will fire the farthest, powder double in quantity or in quality or in fineness? M 53 v.

DRAWBRIDGE

[*Drawing*]

Plan of drawbridge which Donnino showed me.

And because *c* and *d* drive downwards, the space *a b* becomes twisted, consequently it ought to be strengthened by a thick iron bar bent over the wood on the opposite side. M 53 v.

[*Bombards and cross-bows*]

If the bombard has a recoil of a quarter of a braccio how much will it lose in front of its true and suitable range?

If the unlocking of the cross-bow is made with the cross-bow fixed or driven forward or drawn back, what will it lose or gain upon its natural range?

Which of these bombards throws farthest and how far? M 54 r.

[*Breeches of bombards*]

That part of the bronze is most compressed within its mould which is most liquid.

And that is most liquid which is hottest, and that is hottest which comes first out of the furnace. One ought therefore always to make first in the casting that part of the cannon which has to receive the powder before that which has to contain the muzzle.

A long breech is an embarrassment and fills up space uselessly and unserviceably and causes loss of speed. M 54 v.

[*Mines*]

If you wish to find out where a mine runs set a drum over all the places where you suspect the mine is being made and on this drum set a pair of dice, and when you are near the place where the mining is the dice will jump up a little on the drum, through the blow given underground in digging out the earth.

There are some who having the advantage of a river or swamps upon their land have made a great reservoir near the place where they suspect that the mine may be made, and have made a tunnel in the direction of the enemy, and having found them have unlocked the waters of the reservoir upon them and drowned a great number of people in the mine. M.S. 2037 Bib. Nat. 1 r.

The shields of footsoldiers ought to be of cotton spun into thread and made into cords; these should be woven tightly in a circle after the fashion of a buckler.

And if you so wish the threads should be thoroughly moistened before you make cords of them, and then smeared with the dross of iron reduced to powder.

Then plait it in cords a second time with two, then with four, then with eight, and soak them every time in water with borax or linseed or the seed of quinces. And when you have made your cord weave the shield. And if you make a doublet let it be supple, light and impenetrable. MS. 2037 Bib. Nat. 7 r.

If it should happen when a town is besieged that the mines made by the enemy have not penetrated within it, you should place men with the greatest possible care at intervals of ten braccia in that quarter in which your suspicions centre, with their ears on the ground, and as soon as the tremor of the sound reaches them, let them make a very deep trench crosswise, which will be ready to swallow up the mine when it comes upon it. Then have ready a vessel of iron or copper perforated at the bottom, and in the hole have placed the nozzle of a smith's bellows, and then cover over the mouth with a plate of iron, perforated in many places, and fill it with fine feathers; and you turn the mouth in the direction of the mine when it is discovered and blow with the bellows, after having first caused the bellows to be mixed with sulphur and burnt, and the smoke that issues forth will drive away the enemy.

If however you do not wish to make the above-named trench within the circuit of the walls, in order not to interfere with the rounds of the soldiers who are defending the walls, you should make a drill as was shown above, and with this at intervals of two braccia you make a hole six braccia in depth, and make these in a circular line within the walls following the circle of the walls, and let it be as long as you suspect the mine to be. And every hour you excavate these holes one by one and measure them afresh within with a rod, comparing with them the former measurements of the holes, and if the rod should sink down then know that the mine is there and cause them to dig there and there make your defence.

Or if you do not wish to make the test with the rod in order to discover a mine, go every hour with a light above each hole, and when you come to the hole which is above the mine the light will be immediately extinguished. MS. 2037 Bib. Nat. 8 v.

When besieged by ambitious tyrants I find a means of offence and defence in order to preserve the chief gift of nature, which is liberty; and first I would speak of the position of the walls, and then of how the various peoples can maintain their good and just lords.

MS. 2037 Bib. Nat. 10 r.

Of the power of the bombard and the resistance of the object struck, that is that the ball will subdue a wall of one braccio and of two braccia and so of any thickness. Forster II 6 r.

OF MOVEMENT

Prove in the model of the mangonel, which does not become exhausted as does the cross-bow, and mark with the same weight to what distances the different weights thrown by it are carried, and further in respect of the throwing of the same weight see how to vary the counterpoise for the mangonel. Forster II 8 r.

Remember that the more powder there is in the carbine the more the length of the barrel is diminished, so that you have to pay attention to the proportions of your forces. Forster II 39 r.

If you wish to escape from a city or other closed-in place, fill the door-lock with powder from the carbines and set fire to it; also when about to scale walls it will be useful in driving the enemies from the battlements with its blaze. Forster II 49 r.

What substance is it which offers most resistance to the percussion of the bombard, i. e. to its passage? Forster II 53 r.

[*Drawing*]

Length ten braccia; ball an inch thick and ten long; the shape should taper somewhat. Forster II 56 v.

OF MOVEMENT

That bombard discharges its ball to the farthest distance from itself which breaks its obstacles most. Forster II 57 r.

Of the bombards narrow at the base and wide at the mouth, and so of those straight and those curved, and similarly of the tails narrow at the end and wide at the mouth; and the proof is by the flames when it is discharged. Forster II 58 r.

OF PERCUSSION

Make a rule to apply to every description of ball, of iron as of lead or stone, how you ought to increase or diminish the amount of powder. Forster II 62 r.

OF THE SPEED OF BOMBARDS WITH EQUAL TIME, POWDER AND WEIGHT OF BALL

Of many bombards equal in respect of powder and ball, that from which in equal time there is kindled a greater quantity of fire, will hurl its ball more swiftly and to a greater distance.

Of balls of equal weight that which is the swifter will seem heavier and will produce a greater percussion. Forster II 71 r.

If the bombard has its stone flattened like a cheese, and the hollow of the bombard has a like shape, and the centre—the centre of the tail—does not encounter the centre of the stone, so that it goes revolving through the air, it will undoubtedly be exceedingly swift.

For if you take a ball of six ounces and a wheel of like weight without angles at its edges, you will see how much greater a distance the one will be sent by its mover than the other; and this is also due in part to the revolving of its additional substance. And this happens because as the balls are equal in weight, from being round it strikes more air and finds more resistance, and from being flattened it enters upon the air edgewise and penetrates it more rapidly, and more rapidly moves through it. Forster II 72 r.

[*War Machines: with drawing*]

When this is going through its own ranks, it is necessary to raise the machinery that moves the scythes, in order to prevent their doing any harm to anyone.

How the armoured car is arranged inside.

It will need eight men to work it and make it turn and pursue the enemy.

This is good to break through the ranks, but it must be followed up.

B.M. Drawings

XXVII

Naval Warfare

'Construct it so that the wine-skin which serves as a boat, and the implements and the man who is there, shall be midway between the surface and the bottom of the sea.'

[*Notes relating to a submarine attack*]

Do not impart your knowledge and you will excel alone.

Choose a simple youth and have the dress stitched at home.

Stop the galleys of the captains and afterwards sink the others and fire with the cannon on the fort.

[*With drawings of parts of the apparatus*]

Everything under water, that is all the fastenings.

Here stands the man. Doublet. Hose. Level frame.

[*With drawing of small boat under poop of large*]

When the watch has gone its round, bring a small skiff under the poop and set fire to the whole all of a sudden.

[*With drawing of boat and chain*]

To fasten a galley to the bottom *m* on the side opposite to the anchor.

[*With drawing of figure in diving dress (half length)*]

A breastplate of armour together with hood, doublet and hose, and a small wine-skin for use in passing water, a dress for the armour, and the wine-skin to contain the breath, with half a hoop of iron to keep it away from the chest. If you have a whole wine-skin with a valve from the [?ball MS. *da pal . . . ?palla*], when you deflate it, you will go to the bottom, dragged down by the sacks of sand; when you inflate it, you will come back to the surface of the water.

A mask with the eyes protruding made of glass, but let its weight be such that you raise it as you swim.

Carry a knife which cuts well so that a net does not hold you prisoner.

Carry with you two or three small wine-skins, deflated, and capable of being inflated like balls in case of need.

Take provisions as you need them, and having carefully wrapped them up hide them on the bank. But first have an understanding about the agreement, how the half of the ransom is to be yours without deduction; and the store-room of the prisons is near to Manetti, and payment may be made into the hand of Manetti, that is, of the said ransom.

Carry a horn in order to give a signal whether or no the attempt has been successful.

You need to take an impression[1] of one of the three iron screws of the workshop of Santa Liberata, the figure in plaster and the cast in wax.

[*With drawing of figure of man in diving dress. His right arm extended holds a staff which touches a square of cork. Two bags suspended from shoulders*]

It separates from the dress if it should be necessary to break it.

Cork which is to be fixed midway between the surface and the bottom.

Bags of sand.

Carry forty braccia of rope fastened to a bag of sand.[2] C.A. 333 v. a

I will destroy the harbour.

Unless you surrender within four hours you will go to the bottom.

[*Notes with drawings of three heads showing diving apparatus fitted over the nostrils*]

Have the said bag for your mouth ready for use when you are in the sea—for was not this your secret?

[1] MS. has *protare* for which Piumati in his transcript of the Codice Atlantico reads *portare*. I have adopted Müller-Walde's reading, *prontare* for *improntare*.

[2] Alvise Manetti was sent by the Venetian senate on a legation to the Turks, which lasted from October 1499 to the end of March 1500, to attempt some arrangement for the surrender of the Venetian prisoners who were removed from Constantinople to Lepanto after the capture of that fortress by the Turks in August 1499. Already in February 1500 a despatch from Manetti had arrived in Venice which showed that his endeavours were not likely to reach a successful issue. It was presumably at about this time that Leonardo, who was then in Venice, set himself to devise some method of securing the release of the prisoners through the agency of Manetti, and also to consider a plan for destroying the enemy's ships in the harbour by piercing them below the water-line

Try it first for four hours.

Pack-thread.

Of bronze, which is fastened with a screw that has been oiled, it should have been made in a mould. C.A. 346 r. a

[*Drawing of buoy, below which, connected by a long bar, that moves freely on swivels, hangs what is apparently a very large awl or borer. At the side of the buoy a long tube is fastened so that one end projects just above it; it is bound by a number of rings, and its lower end terminates in a sort of bag, which is apparently fixed over the mouth of the diver. A dotted horizontal line shows that this is level with the top of the borer*]

Line to find the middle.

In case you have to make use of the sea make an armour of copper by setting the plates one above another thus: [*drawing*]. That is, one inside the other, so that a hook may not grapple you.

Measure first the depth, and if you see that it will be sufficient merely to bore without sinking the ship, pursue that course; otherwise fasten it in the way indicated.

Hole by which the water makes its exit when the ring is lowered.

Oars. Twelve braccia the lever. Twelve braccia. For the final turn you need a bent lever. In order to turn this screw use a pair of slippers with heels, or hooks, so that the foot may stand firm.

These are the implements which belong to it; but construct it so that the wine-skin which serves as a boat, and the implements and the man who is there, shall be midway between the surface and the bottom of the sea; and have a valve put in this wine-skin, so that when it is deflated it will sink to the bottom where your station is, and the hands will serve as oars.

The way of wings.

The smoke of [. . .] for use as an opiate.

Take seed of darnel as remedy, and [. . .] spirits of wine in cotton. Some white henbane. Some teasel.

Seed and root of *mappello*[?],[1] and dry everything; mix this powder with camphor and it is made.

[1] *Mappello*, an as yet unidentified tree or shrub. In a passage in C.A. 214 r. a it is said to grow plentifully in the Valsasina, which is to the south of Lake Como.

Deadly smoke (*fumo mortale*):
Take arsenic and mix with sulphur or realgar.
Remedy rose water.
Venom of toad, that is, a land-toad.
Slaver of mad dog and decoction of dogwood berries.
Tarantula from Taranto.
Powder of verdigris or of chalk mixed with poison to throw on ships. C.A. 346 v. a

GREEK FIRE

Take charcoal of willow, and saltpetre, and aqua vitæ, and sulphur, pitch, with incense and camphor and Ethiopian wool, and boil them all up together. This fire is so eager to burn that it will run along wood even when it is under water. You should add to the mixture liquid varnish, petroleum,[1] turpentine, and strong vinegar, and mix everything together and dry it in the sun or in an oven when the bread has been taken out, and then stick it round hempen or other tow, moulding it to a round form and driving very sharp nails into every side of it. Leave however an opening in this ball to serve for a fuse, and then cover it with resin and sulphur.

This fire moreover, when fixed to the top of a long lance, which has a braccio of its point covered with iron in order that it may not be burnt by it, is useful for avoiding and warding off the hostile ships in order not to be overwhelmed by their onset.

Throw also vessels of glass filled with pitch on to the ships of the enemy when their crews are engaged in the battle, and by then throwing similar lighted balls after these you will have it in your power to set every ship on fire. Tr. 43 a

Ships made of beams.

Ships made of osier twigs woven and bound with leather for privateers.

In order to fight against walls which face the sea or towers, withdraw the galleys, and before they come to the encounter raise the oars within so that the edges touch together, and move the ship with the

[1] MS. *olio petrolio.*

oars of the back part; in this manner it will seem one only, upon which you will set tower and fort strong and suitable for carrying any artillery that will be serviceable for the battle. Tr. 71 a

[*With drawing*]

These cortalds should be placed upon stout ships, and these two cortalds will have—fastened by a strong chain or a new rope soaked in water—a scythe twelve braccia long and a foot wide at the centre, and with the back of the blade of the thickness of a finger; and one ought to be able to fire both of them at the same time. B 49 r.

[*With drawing*]

To throw poison in the form of powder upon galleys.

Chalk, fine sulphide of arsenic, and powdered verdigris may be thrown among the enemy ships by means of small mangonels. And all those who, as they breathe, inhale the said powder with their breath will become asphyxiated.

But take care to have the wind so that it does not blow the powder back upon you, or to have your nose and mouth covered over with a fine cloth dipped in water so that the powder may not enter. It would also be well to throw baskets covered with paper and filled with this powder from the crow's nest or the deck of the ship. B 69 v.

[*With drawings*]

Ship with scorpions suitable for cutting the ropes of the big ships; from one tip of the sickles to the other should be four braccia; and the sickle should be of the shape of a crescent, one foot at its maximum width and of the breadth of a finger. B 76 r.

[*With drawings*]

Circunfulgore. The *circunfulgore* is a naval machine invented by the inhabitants of Majorca. It is formed of a circle of bombards, of as many as you please provided that the number is not uneven, since in order that the blow may be a vigorous one and yet the vessel may not spring back it is necessary that one bombard should serve as a support and obstacle of another, and in order to effect this it is necessary to set fire at the same instant to two bombards placed opposite to each other, so that if one wishes to flee on one side the other opposes it.
B 82 v.

[*With drawing*]

Lances of considerable length fitted with short rockets should be placed within the edges of the ships, and these may be set on fire by means of a thin cord which comes down the length of the pole as far as the hand. B 83 r.

HOW TO STAVE IN THE BOWS OF A SHIP

[*With drawing*]

It is necessary first that they be engaged, that is fastened together in such a way that you for your part can unlock yourself at your pleasure, so that when the ship goes to the bottom it may not drag yours with it. Let this be done as follows:—draw a weight up to a height and then release it; and as it falls it will give such a blow as a pile-driver gives, and in falling it will draw back the head of a beam which is in equilibrium when upright, and as the head of the aforesaid beam comes back the end that is below advances and staves in the bow of the ship. But see to it that the beam has a cutting edge so that as it rushes to give the stroke the water does not offer resistance to it. And above all see that the chains which hold the ships fastened together are such as can at your pleasure be severed from your side, so that the enemy's ship when it sinks may not drag you down with it.
B 90 V.

[*Drawing*]

If in a battle between ships and galleys the ships are victors because of the height of their mast-heads, you should draw the lateen yard almost up to the top of the mast and attach to the extremity of this yard—at the end that is which projects towards the enemy—a small cage wrapped at the bottom and all round with a large mattress stuffed with cotton to prevent it from being damaged by bombs.

Then draw down the other end of the lateen yard by means of the capstan, and the cage at the opposite end will go up to such a height that it will be far above the mast-head of the ship, and you will easily be able to drive out the men who are within it.

But it is necessary that the men in the galley should go to the opposite side so that they may counterbalance the weight of the men posted in the cage of the lateen yard. MS. 2037 Bib. Nat. 1 v.

[*Drawing*]

If you wish to build a fleet for action you should make use of these ships in order to ram the enemy's ships, that is, make ships a hundred feet[1] in length and eight feet wide and arrange them so that the rowers of the left oars sit on the right side of the ship and the rowers of the right oars on the left side, as is shown at *M* (*figure*), in order that the leverage of the oars may be longer. And this ship should be a foot and a half in thickness, that is made of beams fastened inside and outside by planks set crosswise.

And let the vessel have fastened to it a foot below the water's edge a spike shod with iron of the weight and size of an anvil. And by the might of the oars this vessel will be able to draw back after it has struck the first blow, and will then hurl itself forward again with fury and deal the second blow and then the third, and so many others as to destroy the ship. MS. 2037 Bib. Nat. 3 r

[*Drawing*]

Shape of the vessel [?bomb-ketch] which carries the mortars described above. And I would specially remind you to aim the cannon-balls attached to scythes towards the mast-head where many ropes unite and where the scythes will be effective.

The scythes should be four braccia long and four braccia from one point to the other. And they should be shot among the ropes of the big ships so as to make the sails fall down. And let the ketch which carries them carry a sufficient quantity; and let it be of stout beams so that the cannon from the ships may not break them in pieces; and let the cannon-balls be of two hundred pounds.

MS. 2037 Bib. Nat. 4 v.

[*Drawings*]

Of the means of defence in case the enemy should throw soft soap, or caltrops, or small boards studded with nails, or similar things upon the ships.

[1] Dimensions here given in feet, more usually in braccia. According to Fanfani's Dictionary, a foot was about 30 centimetres, and a braccio (fiorentino) was 58 centimetres.

You should do this:—keep, when you go into the combat, on your feet, underneath your shoes, iron soles, divided in the middle as is shown in the drawing above, so that it is possible to bend the feet; and the underside of these soles should have the form of a rasping file, or be filled with blunted points of nails, in order to prevent the soap from causing the foot to slip and so making the man fall down flat; and, as they are of iron, the small boards and caltrops will be thrown in vain. MS. 2037 Bib. Nat. 6 v.

A SCORPION

[*Figures*]

This machine is so constructed that the scythe springs up when it is discharged; and the ships which carry scythes should be of this sort, namely without either mast or sail and with a great quantity of oars so that they may be swift; without a sail because the sail, mast and cordage would interfere with the working of the great scythe. The machine is called a scorpion because of its resemblance to one and because of the damage it inflicts with its tail. Mantelets are fixed over the rowers in order that the masts, that is to say the mast-heads, or rather the combatants at the mast-heads, may not be able to do them any injury; and these should be covered with moist hides because of the fire thrown by the enemy.

A way of protecting against it is for ships to be provided with chains of rope to a height of six braccia.

[*Figure*] This ship is to serve as a defence against cannon, and it attacks the other ships with its cannon; it is covered with sheet metal[1] as a protection against fire, and bristling with points of nails so that the enemy may not leap upon it with impunity. MS. 2037 Bib. Nat. 8 r.

[*Drawing*]

Some of the combatants in the Tyrrhenian Sea employ this method: they fasten an anchor to one end of the lateen yard and a rope to the other, and this rope at the bottom end is attached to another anchor. In the fight they hook the first anchor to the oars of the enemy's ship and by the force of the capstan draw it to the side.

[1] MS. *coperto di tole.*

And they throw soft soap and tow, dipped in melted pitch and set alight, on the side to which the anchor was first made fast, so that in order to escape from this fire the defenders of the ship have to flee to the opposite side; and by doing so they rendered assistance to their assailants, for the galley was drawn to the side more easily because of this counterpoise. MS. 2037 Bib. Nat. 9 r.

[*Drawing*]

I have found in the history of the Spaniards how, in their wars with the English, Archimedes the Syracusan, who was then living at the court of Eclideride, King of the Cirodastri, ordered that for maritime combats the ships should have tall masts, and on the tops of these he placed a small yard forty feet in length and a third of a foot wide, having at one end of it a small anchor and at the other a counterpoise.

To the anchor was attached twelve feet of chain, and to the chain as much rope as would reach from the chain to the base of the mast-top where it was fixed by a small rope, going down from this base to the base of the mast where a very strong capstan was placed, and there the end of the cord was fastened. But to go back to the use of the machine, I say that below this anchor there was a fire which with a loud roar threw out its rays and a shower of burning pitch, and as this shower fell upon the enemy's mast-top it compelled the men stationed there to abandon their post; and consequently the anchor being lowered by means of the capstan touched the sides of the mast-top, and thus instantly cut the rope placed at the base of the mast-top to support the rope which went from the anchor to the capstan. And drawing the ship . . . MS. 2037 Bib. Nat. 9 v.

How by an appliance many are able to remain for some time under water. How and why I do not describe my method of remaining under water for as long a time as I can remain without food; and this I do not publish or divulge on account of the evil nature of men who would practice assassinations at the bottom of the seas, by breaking the ships in their lowest parts and sinking them together with the crews who are in them; and although I will furnish particulars of others they are such as are not dangerous, for above the surface of the water emerges the mouth of the tube by which they draw in breath, supported upon wine-skins or pieces of cork.[1] Leic. 22 v.

Speak with the Genoese about the sea.[2] Leic. 26 v.

[1] These lines are an excerpt from a passage to be found in full in the section on The Nature of Water. A similar practice has been followed in the case of one or two lines reproduced in the sections entitled Music, Personalia and Dated Notes.

[2] This is one of those enigmatic notes which have given rise to conjecture. It undoubtedly may refer to naval preparations, which were being taken by the Genoese as part of Ludovic Sforza's concerted schemes of defence against the assaults with which he was threatened. As he knew of Leonardo's study of marine warfare he would find him a very suitable agent to send on such a mission. This is incontestable. But the fact remains that this sentence, which is all that exists to connect Leonardo with Genoa, is a comparatively slight foundation for the structure of hypothesis that has been raised upon it.

XXVIII

Comparison of the Arts

'If you know how to describe and write down the appearance of the forms, the painter can make them so that they appear enlivened with lights and shadows which create the very expression of the faces; herein you cannot attain with the pen where he attains with the brush.'

How painting surpasses all human works by reason of the subtle possibilities which it contains:

The eye, which is called the window of the soul, is the chief means whereby the understanding may most fully and abundantly appreciate the infinite works of nature; and the ear is the second, inasmuch as it acquires its importance from the fact that it hears the things which the eye has seen. If you historians, or poets, or mathematicians had never seen things with your eyes you would be ill able to describe them in your writings. And if you, O poet, represent a story by depicting it with your pen, the painter with his brush will so render it as to be more easily satisfying and less tedious to understand. If you call painting 'dumb poetry', then the painter may say of the poet that his art is 'blind painting'. Consider then which is the more grievous affliction, to be blind or to be dumb! Although the poet has as wide a choice of subjects as the painter, his creations fail to afford as much satisfaction to mankind as do paintings, for while poetry attempts to represent forms, actions and scenes with words, the painter employs the exact images of these forms in order to reproduce them. Consider, then, which is more fundamental to man, the name of man or his image? The name changes with change of country; the form is unchanged except by death.

And if the poet serves the understanding by way of the ear, the painter does so by the eye, which is the nobler sense.

I will only cite as an instance of this how if a good painter represents the fury of a battle and a poet also describes one, and the two descriptions are shown together to the public, you will soon see which will draw most of the spectators, and where there will be most discussion, to which most praise will be given and which will satisfy the more. There is no doubt that the painting, which is by far the more useful and beautiful, will give the greater pleasure. Inscribe in any place the name of God and set opposite to it His image, you will see which will be held in greater reverence!

Since painting embraces within itself all the forms of nature, you have omitted nothing except the names, and these are not universal like the forms. If you have the results of her processes we have the processes of her results.

Take the case of a poet describing the beauties of a lady to her lover and that of a painter who makes a portrait of her; you will see whither nature will the more incline the enamoured judge. Surely the proof of the matter ought to rest upon the verdict of experience!

You have set painting among the mechanical arts! Truly were painters as ready equipped as you are to praise their own works in writing, I doubt whether it would endure the reproach of so vile a name. If you call it mechanical because it is by manual work that the hands represent what the imagination creates, your writers are setting down with the pen by manual work what originates in the mind. If you call it mechanical because it is done for money, who fall into this error—if indeed it can be called an error—more than you yourselves? If you lecture for the Schools do you not go to whoever pays you the most? Do you do any work without some reward?

And yet I do not say this in order to censure such opinions, for every labour looks for its reward. And if the poet should say, 'I will create a fiction which shall express great things', so likewise will the painter also, for even so Apelles made the Calumny. If you should say that poetry is the more enduring,—to this I would reply that the works of a coppersmith are more enduring still, since time preserves them longer than either your works or ours; nevertheless they show but little imagination; and painting, if it be done upon copper in enamel colours, can be made far more enduring.

In Art we may be said to be grandsons unto God. If poetry treats of moral philosophy, painting has to do with natural philosophy; if the one describes the workings of the mind, the other considers what the mind effects by movements of the body; if the one dismays folk by hellish fictions, the other does the like by showing the same things in action. Suppose the poet sets himself to represent some image of beauty or terror, something vile and foul, or some monstrous thing, in contest with the painter, and suppose in his own way he makes a change of forms at his pleasure, will not the painter still satisfy the more? Have we not seen pictures which bear so close a resemblance to the actual thing that they have deceived both men and beasts?

If you know how to describe and write down the appearance of the forms, the painter can make them so that they appear enlivened with lights and shadows which create the very expression of the faces; herein you cannot attain with the pen where he attains with the brush. MS. 2038 Bib. Nat. 19 r. and v., 20 r.

How he who despises painting has no love for the philosophy in nature:

If you despise painting, which is the sole imitator of all the visible works of nature, it is certain that you will be despising a subtle invention which with philosophical and ingenious speculation takes as its theme all the various kinds of forms, airs and scenes, plants, animals, grasses and flowers, which are surrounded by light and shade. And this truly is a science and the true-born daughter of nature, since painting is the offspring of nature. But in order to speak more correctly we may call it the grandchild of nature; for all visible things derive their existence from nature, and from these same things is born painting. So therefore we may justly speak of it as the grandchild of nature and as related to God himself. MS. 2038 Bib. Nat. 20 r.

That sculpture is less intellectual than painting, and lacks many of its natural parts:

As practising myself the art of sculpture no less than that of painting, and doing both the one and the other in the same degree, it seems to me that without suspicion of unfairness I may venture to give an opinion as to which of the two is the more intellectual, and of the greater difficulty and perfection.

In the first place, sculpture is dependent on certain lights, namely those from above, while a picture carries everywhere with it its own light and shade; light and shade therefore are essential to sculpture. In this respect, the sculptor is aided by the nature of the relief, which produces these of its own accord, but the painter artificially creates them by his art in places where nature would normally do the like. The sculptor cannot render the difference in the varying natures of the colours of objects; painting does not fail to do so in any particular. The lines of perspective of sculptors do not seem in any way true; those of painters may appear to extend a hundred miles beyond the work itself. The effects of aerial perspective are outside the scope of sculptors' work; they can neither represent transparent bodies nor luminous bodies nor angles of reflection nor shining bodies such as mirrors and like things of glittering surface, nor mists, nor dull weather, nor an infinite number of things which I forbear to mention lest they should prove wearisome.

The one advantage which sculpture has is that of offering greater resistance to time; yet painting offers a like resistance if it is done upon thick copper covered with white enamel and then painted upon with enamel colours and placed in a fire and fused. In degree of permanence it then surpasses even sculpture.

It may be urged that if a mistake is made it is not easy to set it right, but it is a poor line of argument to attempt to prove that the fact of a mistake being irremediable makes the work more noble. I should say indeed that it is more difficult to correct the mind of the master who makes such mistakes than the work which he has spoiled.

We know very well that a good experienced painter will not make such mistakes; on the contrary, following sound rules he will proceed by removing so little at a time that his work will progress well. The sculptor also if he is working in clay or wax can either take away from it or add to it, and when the model is completed it is easy to cast it in bronze; and this is the last process and it is the most enduring form of sculpture, since that which is only in marble is liable to be destroyed, but not when done in bronze.

But painting done upon copper, which by the methods in use in painting may be either taken from or altered, is like the bronze, for when you have first made the model for this in wax it can still be either reduced or altered. While the sculpture in bronze is imperishable this painting upon copper and enamelling is absolutely eternal; and while bronze remains dark and rough, this is full of an infinite variety of varied and lovely colours, of which I have already made mention. But if you would have me speak only of panel painting I am content to give an opinion between it and sculpture by saying that painting is more beautiful, more imaginative, and richer in resource, while sculpture is more enduring, but excels in nothing else.

Sculpture reveals what it is with little effort; painting seems a thing miraculous, making things intangible appear tangible, presenting in relief things which are flat, in distance things near at hand.

In fact, painting is adorned with infinite possibilities of which sculpture can make no use. MS. 2038 Bib. Nat. 25 v. and 24 v.

One of the chief proofs of skill of the painter is that his picture should seem in relief, and this is not the case with the sculptor, for in this respect he is aided by nature. C.A. 305 r. a

[*Of poetry and painting*]

When the poet ceases to represent in words what exists in nature, he then ceases to be the equal of the painter; for if the poet, leaving such representation, were to describe the polished and persuasive words of one whom he wishes to represent as speaking, he would be becoming an orator and be no more a poet or a painter. And if he were to describe the heavens he makes himself an astrologer, and a philosopher or theologian when speaking of the things of nature or of God. But if he returns to the representation of some definite thing he would become the equal of the painter if he could satisfy the eye with words as the painter does with brush and colour, [for with these he creates] a harmony to the eye, even as music does in an instant to the ear.

Quaderni III 7 r.

[*Painting and sculpture*]

Why the picture seen with two eyes will not be an example of such relief as the relief seen with two eyes; this is because the picture seen with one eye will place itself in relief like the actual relief, having the same qualities of light and shade. Quaderni III 8 r.

XXIX

Precepts of the Painter

'Painting is concerned with all the ten attributes of sight, namely darkness, brightness, substance and colour, form and place, remoteness and nearness, movement and rest; and it is with these attributes that this my small book will be interwoven.'

WHICH is the more difficult: light and shade or good design?

I maintain that a thing which is confined by a boundary is more difficult than one which is free. Shadows have their boundaries at certain stages, and when one is ignorant of this his works will be lacking in that relief which is the importance and the soul of painting. Design is free, in so much as if you see an infinite number of faces they will be all different, one with a long nose and one with a short; the painter therefore must also assume this liberty, and where there is liberty there is no rule. MS. 2038 Bib. Nat. 1 r.

PAINTING

The mind of the painter should be like a mirror which always takes the colour of the thing that it reflects, and which is filled by as many images as there are things placed before it. Knowing therefore that you cannot be a good master unless you have a universal power of representing by your art all the varieties of the forms which nature produces,—which indeed you will not know how to do unless you see them and retain them in your mind,—look to it, O Painter, that when you go into the fields you give your attention to the various objects, and look carefully in turn first at one thing and then at another, making a bundle of different things selected and chosen from among those of less value. And do not after the manner of some painters who when tired by imaginative work, lay aside their task and take exercise by walking, in order to find relaxation, keeping, however, such weariness of mind as prevents them either seeing or being conscious of different objects; so that often when meeting friends or relatives, and being saluted by them, although they may see and hear them they know them no more than if they had met only so much air.

MS. 2038 Bib. Nat. 2 r.

The various contrasts of the different degrees of shadows and lights often cause hesitation and confusion to the painter who aspires to imitate and reproduce the things that he sees. The reason is that if you see a white cloth side by side with a black one, it is certain that the part of this white cloth which is next to the black will seem whiter by far than the part that is next to something whiter than itself, and the reason of this is proved in my Perspective.

OF THE NATURE OF THE FOLDS OF DRAPERIES

That part of the fold which is farthest from the ends where it is confined will return most closely to its original form. Everything naturally desires to remain in its own state. Drapery being of uniform density and thickness on the reverse and on the right side, desires to lie flat; consequently, whenever any folds or pleats force it to depart from this condition of flatness, it obeys the law of this force in that part of itself where it is most constrained, and the part farthest away from such constraint you will find return most nearly to its original state, that is to say, lying extended and full. MS. 2038 Bib. Nat. 4 r.

The body of the atmosphere is full of an infinite number of the pyramids composed of radiating straight lines which are caused by the boundaries of the surfaces of the bodies in shadow that are found there, and the farther they are away from the object which produces them the more their angle becomes acute. And although they intersect and interlace in their passage, nevertheless they do not become confused with each other but proceed with divergent course, spreading themselves out and becoming diffused through all the surrounding air.

And they are of equal power among themselves, all equal to each, and each equal to all, and by means of them are transmitted the images of the objects, and these are transmitted all in all, and all in each part; and each pyramid receives of itself in each of its smallest parts the whole form of the object which produces it.

MS. 2038 Bib. Nat. 6 v.

PRECEPTS OF PAINTING

Let the sketches for historical subjects be rapid, and the working of the limbs not too much finished. Content yourself with merely giving the positions of these limbs, which you will then be able at your leisure to finish as you please. MS. 2038 Bib. Nat. 8 v.

Among shadows of equal strength that which is nearest to the eye will seem of less density. MS. 2038 Bib. Nat. 9 v.

All colours in distant shadows are indistinguishable and undiscernible.

In the distance all colours are indistinguishable in shadows, because an object which is not touched by the principal light has no power to transmit its image through the more luminous atmosphere to the eye, because the lesser light is conquered by the greater.

For example, we see in a house that all the colours on the surface of the walls are visible instantly and clearly when the windows of the house are open; but, if we go out of the house and look through the windows at a little distance in order to see the paintings on the walls, we shall see instead of them a uniform darkness.

The painter ought first to exercise his hand by copying drawings by good masters; and having acquired facility in this under the advice of his instructor, he ought to set himself to copy good reliefs, following the rules given below.

OF DRAWING FROM RELIEF

He who draws from relief ought to take his position so that the eye of the figure he is drawing is on a level with his own. And this should be done whenever a head has to be drawn from nature, because generally figures or people whom you meet in the streets all have their eyes at the same level as yours, and if you make them higher or lower you will find that your portrait will not resemble them.

OF THE WAY TO DRAW FIGURES FOR HISTORIES

The painter ought always to consider, as regards the wall on which he intends to represent a story, the height of the position where he intends to place his characters, so that when he makes studies from nature for this purpose he should have his eye as much below the thing that he is drawing as the said thing appears in the picture above the eye of the spectator: otherwise the work will be deserving of censure.

WHY A PAINTING CAN NEVER APPEAR DETACHED AS DO NATURAL THINGS

Painters oftentimes despair of their power to imitate nature, on perceiving how their pictures are lacking in the power of relief and vividness which objects possess when seen in a mirror, though as they allege they have colours that for clearness and depth far surpass the quality of the lights and shadows of the object seen in the mirror, arraigning herein not reason but their own ignorance, in that they fail to recognise the impossibility of a painted object appearing in such relief as to be comparable to the objects in the mirror, although both are on a flat surface unless they are seen by a single eye. And the reason of this is that when two eyes see one thing after another, as in the case of *a b* seeing *n m*, *m* cannot entirely cover *n* because the base of the visual lines is so broad as to cause one to see the second object beyond the first. If however you close one eye as *s*, the object *f* will cover up *r*, because the visual line starts in a single point and makes its base in the first object, with the consequence that the second being of equal size is never seen.

MS. 2038 Bib. Nat. 10 r.

Every bodily form as far as concerns the function of the eye is divided into three parts, namely substance, shape and colour. The image of its substance projects itself farther from its source than its colour or its shape; the colour also projects itself farther than the shape, but this law does not apply to luminous bodies.

The above proposition is clearly shown and confirmed by experience, for if you see a man near at hand you will be able to recognise the character of the substance of the shape and even of the colour, but, if he goes some distance away from you, you will no longer be able to recognise who he is because his shape will lack character, and if he goes still farther away you will not be able to distinguish his colour but he will merely seem a dark body, and farther away still he will seem a very small round dark body. He will appear round because distance diminishes the various parts so much as to leave nothing visible except the greater mass. The reason of this is as follows:—We know very well that all the images of objects penetrate to the imprensiva[1] through a small aperture in the eye; therefore if the whole horizon *a d* enters through a similar aperture and the object *b c* is a very small part of this horizon, what part must it occupy in the minute representation of so great a hemisphere? And since luminous bodies have more power in darkness than any others it is necessary, since the aperture of the sight is considerably in shadow, as is the nature of all holes, that the images of distant objects intermingle within the great light of the sky, or if it should be that they remain visible they appear dark and black, as every small body must when seen in the limpidity of the air. MS. 2038 Bib. Nat. 12 v.

[*Images in the air*]

All bodies together and each of itself fill the surrounding air with an infinite number of their images which are all in all this air, and all in the parts of it, bearing with them the nature of the body, the colour and the form of their cause.

Perspective is the bridle and rudder of painting.

MS. 2038 Bib. Nat. 13 r.

Shadows which you see with difficulty, and whose boundaries you cannot define—but which you only apprehend and reproduce in your work with some hesitation of judgment—these you should not represent as finished or sharply defined, for the result would be that your work would seem wooden.

OF REFLECTION

Reflections are caused by bodies of a bright nature and of a smooth and half-opaque surface, which when struck by the light drive it back again to the first object like the rebound of a ball.

[1] Imprensiva, see Vol. I, Optics, pp. 237-8.

OF WHERE THERE CANNOT BE LUMINOUS REFLECTION

All solid bodies have their surfaces covered by various degrees of light and shadow. The lights are of two kinds: the one is called original the other derived. Original I call that which proceeds from the flame of the fire, or from the light of the sun, or of the atmosphere. Derived light is the light reflected. But, to return to the promised definition, I say that there is no luminous reflection on the side of the body which is turned towards objects in shadow such as shaded scenes, meadows with grasses of varying height, green or bare woods—for these, although the part of each branch turned to the original light is imbued with the attributes of this light, have nevertheless so many shadows cast by each branch separately, and so many shadows cast by one branch on another, that in the whole mass there results such a depth of shadow that the light is as nothing; hence objects such as these cannot throw any reflected light upon bodies opposite to them.

MS. 2038 Bib. Nat. 14 v.

WHY THE REPRESENTING OF GROUPS OF FIGURES ONE ABOVE ANOTHER IS TO BE AVOIDED

This custom, which is universally adopted by painters for the walls of chapels, is by right strongly to be censured, seeing that they represent one composition at one level with its landscape and buildings, and then mount to the stage above it and make another, and so vary the point of sight from that of the first painting, and then make a third, and a fourth, in such a way that the work on the one wall shows four points of sight, which is extreme folly on the part of such masters.

Now we know that the point of sight is opposite the eye of the spectator of the composition, and if you were to ask me how I should represent the life of a saint when it is divided up in several compositions on the same wall, to this I reply that you ought to set the foreground with its point of sight on a level with the eye of the spectators of the composition, and at this same plane make the chief episode on a large scale, and then by diminishing gradually the figures and buildings upon the various hills and plains, you should represent all the incidents of the story. And on the rest of the wall up to the top you should make trees large as compared with the figures, or angels if these are appropriate to the story, or birds or clouds or similar things; but otherwise do not put yourself to the trouble for the whole of your work will be wrong.

Figures in relief in the act of movement will in their standing position seem naturally to fall forward. MS. 2038 Bib. Nat. 16 r.

The youth ought first to learn perspective, then the proportions of everything, then he should learn from the hand of a good master in order to accustom himself to good limbs; then from nature in order to confirm for himself the reasons for what he has learnt; then for a time he should study the works of different masters; then make it a habit to practise and work at his art.

How the first picture was nothing but a line which surrounded the shadow of a man made by the sun upon a wall.

How historical pictures ought not to be crowded and confused by many figures.

How old men should be shown with slow listless movements, with the legs bent at the knees when they are standing up, with the feet parallel and separated one from another, the spine bent low, the head leaning forward, and the arms not too far apart.

How women should be represented in modest attitudes, with legs close together, arms folded, and with their heads low and bending sideways.

How old women should be represented as bold, with swift passionate movements like the infernal furies, and these movements should seem quicker in the arms and heads than in the legs.

Little children should be represented when sitting as twisting themselves about with quick movements, and in shy, timid attitudes when standing up.

How one ought not to give drapery a confusion of many folds, but only make them where it is held by the hands or arms, and the rest may be suffered to fall simply where its nature draws it: and do not let the contour of the figure be broken by too many lines or interrupted folds.

How draperies should be drawn from nature: that is, if you wish to represent woollen cloth draw the folds from the same material, and if it is to be silk, or fine cloth, or homespun, or of linen or crape, show the different nature of the folds in each; and do not make a costume as many make it upon models covered with pieces of paper or thin leather, for you will be deceiving yourself greatly.

MS. 2038 Bib. Nat. 17 v.

OF THE THREE KINDS OF PERSPECTIVE

Perspectives are of three kinds. The first has to do with the causes of the diminution or as it is called the diminishing perspective of objects as they recede from the eye. The second the manner in which colours are changed as they recede from the eye. The third and last consists in defining in what way objects ought to be less carefully finished as they are farther away. And the names are these:

Linear Perspective
Perspective of Colour
Vanishing Perspective.

OF THE FEW FOLDS IN DRAPERIES

How figures when dressed in a cloak ought not to show the shape to such an extent that the cloak seems to be next to the skin; for surely you would not wish that the cloak should be next to the skin, since you must realise that between the cloak and the skin are other garments which prevent the shape of the limbs from being visible and appearing through the cloak. And those limbs which you make visible, make thick of their kind so that there may seem to be other garments there under the cloak. And you should only allow the almost identical thickness of the limbs to be visible in a nymph or an angel, for these are represented clad in light draperies, which by the blowing of the wind are driven and pressed against the various limbs of the figures.

OF THE WAY TO PRESENT DISTANT OBJECTS IN PAINTING

It is evident that the part of the atmosphere which lies nearest the level ground is denser than the rest, and that the higher it rises the lighter and more transparent it becomes.

In the case of large and lofty objects which are some distance away from you, their lower parts will not be much seen, because the line by which you should see them passes through the thickest and densest portion of the atmosphere. But the summits of these heights are seen along a line which, although when starting from your eye it is projected through the denser atmosphere, yet since it ends at the highest summit of the object seen, concludes its course in an atmosphere far more rarefied than that of its base. And consequently the farther away from you this line extends from point to point the greater is the change in the finer quality of the atmosphere.

Do you, therefore, O painter, when you represent mountains, see that from hill to hill the bases are always paler than the summits, and the farther away you make them one from another let the bases be paler in proportion, and the loftier they are the more they should reveal their true shape and colour. MS. 2038 Bib. Nat. 18 r.

How the atmosphere should be represented as paler in proportion as you show it extending lower:

Since the atmosphere is dense near the ground, and the higher it is the finer it becomes, therefore when the sun is in the east and you look towards the west, taking in a part to the north and to the south, you will see that this dense air receives more light from the sun than the finer air, because the rays encounter more resistance. And if your view of the horizon is bounded by a low plain, that farthest region of the sky will be seen through that thicker whiter atmosphere, and this will destroy the truth of the colour as seen through such a medium; and the sky will seem whiter there than it does overhead, where the line of vision traverses a lesser space of atmosphere charged with thick vapours. But if you look towards the east the atmosphere will appear darker in proportion as it is lower, for in this lower atmosphere the luminous rays pass less freely.

How shadows are distributed in different positions, and of the objects situated in them:

If the sun is in the east and you look towards the west you will see that all the things which are illuminated are entirely deprived of shadow, because what you are looking at is what the sun sees.

And if you look to the south and the north you will see that all the bodies are surrounded by light and shade, because you are looking both at the part that does not see and the part that sees the sun. And if you look towards the pathway of the sun all the objects will present their shaded side to you because this side cannot be seen by the sun.

OF THE WAY TO REPRESENT A NIGHT SCENE

Whatever is entirely deprived of light is all darkness. When such is the condition of night, if you wish to represent a scene therein, you must arrange to introduce a great fire there, and then the things which are nearest to the fire will be more deeply tinged with its colour, for whatever is nearest to the object partakes most fully of its nature; and making the fire of a reddish colour you should represent all the things illuminated by it as being also of a ruddy hue, while those which are farther away from the fire should be dyed more deeply with the black colour of the night. The figures which are between you and the fire will appear dark against the brightness of the flame, for that part of the object which you perceive is coloured by the darkness of the night, and not by the brightness of the fire; those which are at the sides should be half in shadow and half in ruddy light; and those visible beyond the edge of the flames will all be lit up with ruddy light against a dark background. As for their actions, show those who are near it making a screen with hands and cloaks as a protection against the unbearable heat, with faces turned away as though on the point of flight; while of those farther away you should show a great number pressing their hands upon their eyes, hurt by the intolerable glare.

MS. 2038 Bib. Nat. 18 v.

Why of two objects of equal size the painted one will look larger than that in relief:

This proposition is not so easy to expound as many others, but I will nevertheless attempt to prove it, if not completely then in part. Diminishing perspective demonstrates by reason that objects diminish in proportion as they are farther away from the eye, and this theory is entirely confirmed by experience. Now the lines of sight which are between the object and the eye are all intersected at a uniform boundary when they reach the surface of the painting; while the lines which pass from the eye to the piece of sculpture have different boundaries and are of varying lengths. The line which is the longest extends to a limb which is farther away than the rest, and consequently this limb appears smaller; and there are many lines longer than others, for the reason that there are many small parts one farther away than another, and being farther away these of necessity appear smaller, and by appearing smaller they effect a corresponding decrease in the whole mass of the object. But this does not happen in the painting, because as the lines of sight end at the same distance it follows that they do not undergo diminution, and as the parts are not themselves diminished they do not lessen the whole mass of the object, and consequently the diminution is not perceptible in the painting as it is in sculpture.

MS. 2038 Bib. Nat. 19 r.

HOW WHITE BODIES OUGHT TO BE REPRESENTED

When you are representing a white body surrounded by ample space, since the white has no colour in itself it is tinged and in part transformed by the colour of what is set over against it. If you are looking at a woman dressed in white in the midst of a landscape the side of her that is exposed to the sun will be so dazzling in colour that parts of it, like the sun itself, will cause pain to the sight, and as for the side exposed to the atmosphere—which is luminous because of the rays of the sun being interwoven with it and penetrating it—since this atmosphere is itself blue, the side of the woman which is exposed to it will appear steeped in blue. If the surface of the ground near to her be meadows, and the woman be placed between a meadow lit by the sun and the sun itself, you will find that all the parts of the folds [of her dress] which are turned towards the meadow will be dyed by the reflected rays to the colour of the meadow; and thus she becomes changed into the colours of the objects near, both those luminous and those non-luminous.

HOW TO REPRESENT THE LIMBS

Make muscular such limbs as have to endure fatigue, and those which are not so used make without muscles and soft.

OF THE ACTION OF FIGURES

Make figures with such action as may be sufficient to show what the figure has in mind; otherwise your art will not be worthy of praise.

MS. 2038 Bib. Nat. 20 r.

OF THE CHOICE OF THE LIGHT WHICH GIVES A GRACE TO FACES

If you have a courtyard which, when you so please, you can cover over with a linen awning, the light will then be excellent. Or when you wish to paint a portrait, paint it in bad weather, at the fall of the evening, placing the sitter with his back to one of the walls of the courtyard. Notice in the streets at the fall of the evening when it is bad weather the faces of the men and women—what grace and softness they display! Therefore, O painter, you should have a courtyard fitted up with the walls tinted in black and with the roof projecting forward a little beyond the wall; and the width of it should be ten braccia, and the length twenty braccia, and the height ten braccia; and you should cover it over with the awning when the sun is on it, or else you should make your portrait at the hour of the fall of the evening when it is cloudy or misty, for the light then is perfect.

WHY FACES AT A DISTANCE APPEAR DARK

We see clearly that all the images of the visible things both large and small which serve us as objects enter to the sense through the tiny pupil of the eye. If, then, through so small an entrance there passes the image of the immensity of the sky and of the earth, the face of man—being almost nothing amid such vast images of things, because of the distance which diminishes it—occupies so little of the pupil as to remain indistinguishable; and having to pass from the outer surface to the seat of the sense through a dark medium, that is, through the hollow cells which appear dark, this image when not of a strong colour is affected by the darkness through which it passes, and on reaching the seat of the sense it appears dark. No other reason can be advanced to account for the blackness of this point in the pupil; and since it is filled with a moisture transparent like the air, it acts like a hole made in a board; and when looked into it appears black, and the objects seen in the air, whether light or dark, become indistinct in the darkness.

OF SHADOWS IN THE FAR DISTANCE

Shadows become lost in the far distance, because the vast expanse of luminous atmosphere which lies between the eye and the object seen suffuses the shadows of the object with its own colour.

WHY A MAN SEEN AT A CERTAIN DISTANCE CANNOT BE RECOGNISED

Diminishing perspective shows us that in proportion as an object is farther away the smaller it becomes. And if you look at a man who is at the distance of a bowshot away from you and put the eye of a small needle close to your eye, you will be able through this to see the images of many men transmitted to the eye, and these will all be contained at one and the same time within the eye of the said needle. If then the image of a man who is distant from you the space of a bowshot is so transmitted to your eye as to occupy only a small part of the eye of a needle, how should you be able in so small a figure to distinguish or discern the nose or mouth or any detail of the body?

And not seeing these you cannot recognise the man, since he does not show you the features which cause men to differ in appearance.

OF ATTITUDES

The pit of the throat is above the foot. If an arm be thrown forward the pit of the throat moves from above the foot, and if the leg is thrown backwards the pit of the throat moves forwards, and so it changes with every change of attitude. MS. 2038 Bib. Nat. 20 v.

HOW TO REPRESENT A TEMPEST

If you wish to represent a tempest properly, consider and set down exactly what are the results when the wind blowing over the face of the sea and of the land lifts and carries with it everything that is not immovable in the general mass. And in order properly to represent this tempest, you must first of all show the clouds, riven and torn, swept along in the path of the wind, together with storms of sand blown up from the sea shores, and branches and leaves caught up by the irresistible fury of the gale and scattered through the air, and with them many other things of light weight. The trees and shrubs should be bent to the ground, as though showing their desire to follow the direction of the wind, with their branches twisted out of their natural growth and their leaves tossed and inverted. Of the men who are there, some should have fallen and be lying wrapped round by their garments and almost indistinguishable on account of the dust, and those who are left standing should be behind some tree with their arms thrown round it to prevent the wind from dragging them away; others should be shown crouching on the ground, their hands over their eyes because of the dust, their garments and hair streaming in the wind. Let the sea be wild and tempestuous, and between the crests of its waves it should be covered with eddying foam, and the wind should carry the finer spray through the stormy air after the manner of a thick and all-enveloping mist.

Of the ships that are there, some you should show with sail rent and the shreds of it flapping in the air in company with the broken halyards, and some of the masts broken and gone by the board, and the vessel itself lying disabled and broken by the fury of the waves, with some of the crew shrieking and clinging to the fragments of the wreck. You should show the clouds, driven by the impetuous winds, hurled against the high mountain tops, and there wreathing and eddying like waves that beat upon the rocks; the very air should strike terror through the murky darkness occasioned therein by the dust and mist and thick clouds.

OF HOW TO REPRESENT SOMEONE WHO IS SPEAKING AMONG A GROUP OF PERSONS

When you desire to represent anyone speaking among a group of persons you ought to consider first the subject of which he has to treat, and how so to order his actions that they may be in keeping with this subject. That is, if the subject be persuasive, the actions should serve this intention; if it be one that needs to be expounded under various heads, the speaker should take a finger of his left hand between two fingers of his right, keeping the two smaller ones closed,[1] and let his face be animated and turned towards the people, with mouth slightly opened, so as to give the effect of speaking. And if he is seated let him seem to be in the act of raising himself more upright, with his head forward. And if you represent him standing, make him leaning forward a little with head and shoulders towards the populace, whom you should show silent and attentive, and all watching the face of the orator with gestures of admiration. Show the mouths of some of the old men with the corners pulled down in astonishment at what they hear, drawing back the cheeks in many furrows, with their eyebrows raised where they meet, making many wrinkles on their foreheads; and show some sitting with the fingers of their hands locked together and clasping their weary knees, and others—decrepit old men—with one knee crossed over the other, and one hand resting upon it which serves as a cup for the other elbow, while the other hand supports the bearded chin.

MS. 2038 Bib. Nat. 21 r.

How to heighten the apparent relief in a painting by the use of artificial lights and shadows:

In order to increase the relief in a picture you should make it your practice to place between the figure represented and that adjacent object which receives its shadow, a line of bright light in order to divide the figure from the object in shadow. And in this same object you will make two bright parts which shall have between them the shadow cast upon the wall by the figure placed opposite: and do this frequently with the limbs which you desire should stand out somewhat from

[1] MS. has *serate*. M. Ravaisson-Mollien gives *searate*, and translates as though it were 'separate'.

their body; and especially when the arms cross the breast, show how between the line of incidence of the shadow of the arm upon the breast and the real shadow of the arm, there remains a streak of light which seems to pass through the space that is between the breast and the arm. And the more you wish the arm to seem detached from the breast the broader you must make this light. And always make it your aim so to arrange bodies against their backgrounds that the parts of the bodies that are in shadow end against a light background, and the part of the body that is illuminated ends against a dark background.

OF THE SURROUNDING OF BODIES WITH VARIOUS SHAPES OF SHADOW

Take care that the shadows cast upon the surfaces of bodies by different objects are always undulating with varying curves produced by the variety of the limbs that create the shadows and of the object that receives the shadow.

OF THE ESSENTIAL NATURE OF SHADOW

Shadow partakes of the nature of universal things which are all more powerful at their beginning and grow weaker towards the end. I refer to the beginning of all forms and qualities visible or invisible, and not of things brought from small beginnings to a mighty growth by time, as a great oak would be which has its feeble beginning in a tiny acorn; though I would rather say the oak is most powerful at the spot where it is born in the ground, for there is the place of its greatest growth. Darkness, therefore, is the first stage of shadow and light is the last. See, therefore, O painter, that you make your shadow darkest near to its cause and make the end of it become changed into light so that it seems to have no end.

How the shadows cast by particular lights should be avoided because their ends are like their beginnings:

The shadows cast by the sun or other particular lights do not impart grace to the body to which they belong, but rather leave the parts separated in a state of confusion with a visible boundary of shadow and light. And the shadows have the same strength at the end that they had at the beginning. MS. 2038 Bib. Nat. 21 v.

WHAT SHADOW AND LIGHT ARE

Shadow is the absence of light; it is simply the obstruction caused by opaque bodies opposed to luminous rays. Shadow is of the nature of darkness, light is of the nature of brightness. The one hides and the other reveals. They are always in company attached to the bodies. And shadow is more powerful than light for it impedes and altogether deprives objects of brightness, whereas brightness can never altogether drive away shadow from bodies, that is from opaque bodies.

What difference there is between a shadow inseparable from a body and a cast shadow:

An inseparable shadow is one which is never parted from the illuminated bodies, as is the case with a ball, for when it is in the light it always has one of its sides covered by shadow and this shadow never separates from it through any change in the position of the ball. A cast shadow may or may not be produced by the body itself. Let us suppose the ball to be at a distance of a braccio from the wall and the light to be coming from the opposite side: this light will throw just as broad a shadow upon the wall as upon the side of the ball that faces the wall. Part of a cast shadow will not be visible when the light is below the ball, for its shadow will then pass towards the sky and finding there no obstruction in its course will become lost. MS. 2038 Bib. Nat. 22 r.

A WAY TO STIMULATE AND AROUSE THE MIND TO VARIOUS INVENTIONS

I will not refrain from setting among these precepts a new device for consideration which, although it may appear trivial and almost ludicrous, is nevertheless of great utility in arousing the mind to various inventions.

And this is that if you look at any walls spotted with various stains or with a mixture of different kinds of stones, if you are about to invent some scene you will be able to see in it a resemblance to various different landscapes adorned with mountains, rivers, rocks, trees, plains, wide valleys and various groups of hills. You will also be able to see divers combats and figures in quick movement, and strange expressions of faces, and outlandish costumes, and an infinite number of things which you can then reduce into separate and well-conceived forms. With such walls and blends of different stones it comes about as it does with the sound of bells, in whose clanging you may discover every name and word that you can imagine.

OF THE TEN ATTRIBUTES OF SIGHT WHICH ALL FIND EXPRESSION IN PAINTING

Painting is concerned with all the ten attributes of sight, namely darkness and brightness, substance and colour, form and place, remoteness and nearness, movement and rest; and it is with these attributes that this my small book will be interwoven, recalling to the painter by what rules and in what way he ought by his art to imitate all things that are the work of nature and the adornment of the world.

HOW THE PAINTER OUGHT TO PRACTISE HIMSELF IN THE PERSPECTIVE OF COLOURS

As a means of practising this perspective of the variation and loss or diminution of the proper essence of colours, take, at distances a hundred braccia apart, objects standing in the landscape, such as trees, houses, men and places, and in front of the first tree fix a piece of glass so that it is quite steady, and then let your eye rest upon it and trace out a tree upon the glass above the outline of the tree; and afterwards remove the glass so far to one side that the actual tree seems almost to touch the one that you have drawn. Then colour your drawing in such a way that the two are alike in colour and form, and that if you close one eye both seem painted on the glass and the same distance away. Then proceed in the same way with a second and a third tree at distances of a hundred braccia from each other. And these will always serve as your standards and teachers when you are at work on pictures where they can be applied, and they will cause the work to be successful in its distance.

But I find it is a rule that the second is reduced to four-fifths the size of the first when it is twenty braccia distant from it.

OF UNDULATING MOVEMENTS AND EQUIPOISE IN HUMAN FIGURES AND FIGURES OF ANIMALS

Whenever you make a figure of a man or of some graceful animal remember to avoid making it seem wooden; that is it should move with counterpoise and balance in such a way as not to seem a block of wood.

Those whom you wish to represent as strong should not be shown thus except in their manner of turning their heads upon their shoulders. MS. 2038 Bib. Nat. 22 v.

OF LINEAR PERSPECTIVE

Linear perspective has to do with the function of the lines of sight, proving by measurement how much smaller is the second object than the first and the third than the second, and so on continually until the limit of things seen. I find by experience that if the second object is as far distant from the first as the first is from your eye, although as between themselves they may be of equal size, the second will seem half as small again as the first; and if the third object is equal in size to the second, and it is as far beyond the second as the second is from the first,[1] it will appear half the size of the second; and thus by successive degrees at equal distances the objects will be continually lessened by half, the second being half the first—provided that the intervening space does not amount to as much as twenty braccia; for at the distance of twenty braccia a figure resembling yours will lose four-fifths of its size, and at a distance of forty braccia it will lose nine-tenths, and nineteen-twentieths at sixty braccia, and so by degrees it will continue to diminish, when the plane of the picture is twice your own height away from you, for if the distance only equals your own height there is a great difference between the first set of braccia and the second.

[1] MS. has 'third'.

OF PLACING A FIGURE IN THE FOREGROUND IN AN HISTORICAL COMPOSITION

You should make the figure in the foreground in an historical composition proportionately less than life size according to the number of braccia that you place it behind the front line, and then make the others in proportion to the first by the rule above.

I give the degrees of the things seen by the eye as the musician does of the sounds heard by the ear:

Although the things seen by the eye seem to touch as they recede I will nevertheless found my rule on spaces of twenty braccia, as the musician has done with sounds, for although they are united and connected together he has nevertheless fixed the degrees from sound to sound, calling these first, second, third, fourth and fifth, and so from degree to degree he has given names to the varieties of the sound of the voice, as it becomes higher or lower.

A method of making the shadow on figures correspond to their light and their shape:

When you make a figure and wish to see whether the shadow corresponds to the light, and is neither redder nor yellower than is the nature of the essence of the colour which you wish to show in shadow, you should do as follows: with a finger make a shadow upon the illuminated part, and if the accidental shadow made by you is like the natural shadow made by your finger upon your work, it will be well then by moving the finger nearer or farther off, to make the shadows darker or lighter, comparing them constantly with your own.

MS. 2038 Bib. Nat. 23 r.

WHY AN OBJECT WHEN PLACED CLOSE TO THE EYE WILL HAVE ITS EDGES INDISTINCT

All those objects opposite to the eye which are too near to it will have their edges difficult to discern, as happens when objects are near to the light and cast a large and indistinct shadow, even so this does when it has to judge of objects outside it: in all cases of linear perspective its action is similar to that of light. The reason of this is that the eye has one principal line [of vision] which dilates as it acquires distance, and embraces with exactness of perception large things far away as it does small things close at hand. The eye however sends out a multitude of lines on either side of this principal centre-line, and these have less power to discern correctly as they are farther from the centre in this radiation. It follows therefore when an object is placed close to the eye that at that stage of nearness to the principal line of vision this is not capable of distinguishing the edges of the object, and so these edges must needs find themselves amid the lines that have but a poor power of comprehension. Their part in the functions of the eye is like that of setters at the chase, who start the prey but cannot catch it. So while they cannot themselves apprehend them they are a reason why the principal line of vision is diverted to the objects touched by these lines.

It follows therefore that the objects which have their edges judged by these lines are indistinct. MS. 2038 23 v.

OF THE WAY TO LEARN WELL BY HEART

When you wish to know anything well by heart which you have studied follow this method:—When you have drawn the same thing so many times that it seems that you know it by heart try to do it without the model; but have a tracing made of the model upon a thin piece of smooth glass and lay this upon the drawing you have made without the model. Note well where the tracing and your drawing do not tally, and where you find that you have erred bear it in mind in order not to make the mistake again. Even return to the model in order to copy the part where you were wrong so many times as to fix it in your mind; and if you cannot procure smooth glass to make a tracing of the object take a piece of very fine parchment well oiled and then dried, and when you have used it for one drawing you can wipe this out with a sponge and do a second.

OF THE WAY TO REPRESENT A SCENE CORRECTLY

Take a piece of glass of the size of a half sheet of royal folio paper, and fix it well in front of your eyes, that is between your eye and the object that you wish to portray. Then move away until your eye is two-thirds of a braccio away from the piece of glass, and fasten your head by means of an instrument in such a way as to prevent any movement of it whatsoever. Then close or cover up one eye, and with a brush or a piece of red chalk finely ground mark out on the glass what is visible beyond it; afterwards copy it by tracing on paper from the glass, then prick it out upon paper of a better quality and paint it if you so desire, paying careful attention to the aerial perspective.

A WAY OF LEARNING HOW TO PLACE A FIGURE WELL

If you wish thoroughly to accustom yourself to correct and good positions for your figures, fasten a frame or loom divided into squares by threads between your eye and the nude figure which you are representing, and then make the same squares upon the paper where you wish to draw the said nude but very faintly. You should then place a pellet of wax on a part of the network to serve as a mark which as you look at your model should always cover the pit of the throat, or if he should have turned his back make it cover one of the vertebrae of the neck. And these threads will instruct you as to all the parts of the body which in each attitude are found below the pit of the throat, below the angles of the shoulders, below the breasts, the hips and the other parts of the body; and the transverse lines of the network will show you how much higher the figure is above the leg on which it is posed than above the other, and the same with the hips, the knees and the feet. But always fix the net by a perpendicular line and then see that all the divisions that you see the nude take in the network, the nude that you draw takes in the network of your sketch. The squares you draw may be as much smaller than those of the network in proportion as you wish your figure to be less than life size: then keep in mind in the figures that you make, the rule of the corresponding proportions of the limbs as the network has revealed it to you, and this should be three and a half braccia in height and three wide, at a distance of seven braccia from you and one from the nude figure.

MS. 2038 Bib. Nat. 24 r.

HOW THE MIRROR IS THE MASTER OF PAINTERS

When you wish to see whether the general effect of your picture corresponds with that of the object represented after nature, take a mirror and set it so that it reflects the actual thing, and then compare the reflection with your picture, and consider carefully whether the subject of the two images is in conformity with both, studying especially the mirror. The mirror ought to be taken as a guide—that is, the flat mirror—for within its surface substances have many points of resemblance to a picture; namely, that you see the picture made upon one plane showing things which appear in relief, and the mirror upon one plane does the same. The picture is one single surface, and the mirror is the same.

The picture is intangible, inasmuch as what appears round and detached cannot be enclosed within the hands, and the mirror is the same. The mirror and the picture present the images of things surrounded by shadow and light, and each alike seems to project considerably from the plane of its surface. And since you know that the mirror presents detached things to you by means of outlines and shadows and lights, and since you have moreover amongst your colours more powerful shadows and lights than those of the mirror, it is certain that if you but know well how to compose your picture it will also seem a natural thing seen in a great mirror. MS. 2038 Bib. Nat. 24 v.

Of the poor excuse made by those who falsely and unworthily get themselves styled painters:

There is a certain class of painters who though they have given but little attention to study claim to live in all the beauty of gold and azure. These aver—such is their folly!—that they are not able to work up to their best standard because of the poor payment, but that they have the knowledge and could do as well as any other if they were well paid.

But see now the foolish folk! They have not the sense to keep by them some specimen of their good work so that they may say, 'this is at a high price, and that is at a moderate price and that is quite cheap', and so show that they have work at all prices.

MS. 2038 Bib. Nat. 25 r.

OF AERIAL PERSPECTIVE

There is another kind of perspective which I call aerial, because by the difference in the atmosphere one is able to distinguish the various distances of different buildings when their bases appear to end on a single line, for this would be the appearance presented by a group of buildings on the far side of a wall, all of which as seen above the top of the wall look to be the same size; and if in painting you wish to make one seem farther away than another you must make the atmosphere somewhat heavy. You know that in an atmosphere of uniform density the most distant things seen through it, such as the mountains, in consequence of the great quantity of atmosphere which is between your eye and them, will appear blue, almost of the same colour as the atmosphere when the sun is in the east. Therefore you should make the building which is nearest above the wall of its natural colour, and that which is more distant make less defined and bluer; and one which you wish should seem as far away again make of double the depth of blue, and one you desire should seem five times as far away make five times as blue. And as a consequence of this rule it will come about that the buildings which above a given line appear to be of the same size will be plainly distinguished as to which are the more distant and which larger than the others.

HOW THE PAINTER IS NOT WORTHY OF PRAISE UNLESS HE IS UNIVERSAL

We may frankly admit that certain people deceive themselves who apply the title 'a good master' to a painter who can only do the head or the figure well. Surely it is no great achievement if by studying one thing only during his whole lifetime he attain to some degree of excellence therein! But since, as we know, painting embraces and contains within itself all the things which nature produces or which result from the fortuitous actions of men, and in short whatever can be comprehended by the eyes, it would seem to me that he is but a poor master who makes only a single figure well.

For do you not see how many and how varied are the actions which are performed by men alone? Do you not see how many different kinds of animals there are, and also of trees and plants and flowers? What variety of hilly and level places, of springs, rivers, cities, public and private buildings; of instruments fitted for man's use; of divers costumes, ornaments and arts?—Things which should be rendered with equal facility and grace by whoever you wish to call a good painter.

OF DRAWING

Which is better—to draw from nature or from the antique?
And which is more difficult—the lines or the light and shade?

MS. 2038 Bib. Nat. 25 v.

OF STUDYING AS SOON AS YOU ARE AWAKE OR BEFORE YOU GO TO SLEEP IN BED IN THE DARK

I have proved in my own case that it is of no small benefit on finding oneself in bed in the dark to go over again in the imagination the main outlines of the forms previously studied, or of other noteworthy things conceived by ingenious speculation; and this exercise is entirely to be commended, and it is useful in fixing things in the memory.

How the painter ought to be desirous of hearing every man's opinion as to the progress of his work:

Surely when a man is painting a picture he ought not to refuse to hear any man's opinion, for we know very well that though a man may not be a painter he may have a true conception of the form of another man, and can judge aright whether he is hump-backed or has one shoulder high or low, or whether he has a large mouth or nose or other defects.

Since then we recognise that men are able to form a true judgment as to the works of nature, how much the more does it behove us to admit that they are able to judge our faults. For you know how much a man is deceived in his own works, and if you do not recognise this in your own case observe it in others and then you will profit by their mistakes. Therefore you should be desirous of hearing patiently the opinions of others, and consider and reflect carefully whether or no he who censures you has reason for his censure; and correct your work if you find that he is right, but if not, then let it seem that you have not understood him, or, in case he is a man whom you esteem, show him by argument why it is that he is mistaken.

How in works of importance a man should not trust so entirely to his memory as to disdain to draw from nature:

Any master who let it be understood that he could himself recall all the forms and effects of nature would certainly appear to me to be endowed with great ignorance, considering that these effects are infinite and that our memory is not of so great capacity as to suffice thereto.

Do you therefore, O painter, take care lest the greed for gain prove a stronger incentive than renown in art, for to gain this renown is a far greater thing than is the renown of riches.

For these, then, and other reasons which might be given, you should apply yourself first of all to drawing, in order to present to the eye in visible form the purpose and invention created originally in your imagination; then proceed to take from it or add to it until you satisfy yourself; then have men arranged as models draped or nude in the way in which you have disposed them in your work; and make the proportions and size in accordance with perspective, so that no part of the work remains that is not so counselled by reason and by the effects in nature.

And this will be the way to make yourself renowned in your art.

An object which is represented in white and black will appear in more pronounced relief than any other: and therefore I would remind you, O painter, that you should clothe your figures in as bright colours as you can, for if you make them dark in colour they will be only in slight relief and be very little visible at a distance. This is because the shadows of all objects are dark, and if you make a garment dark there will be only a slight difference between its lights and shades, whereas with the bright colours there are many grades of difference.

MS. 2038 Bib. Nat. 26 r.

OF THE WAY TO FIX IN YOUR MIND THE FORM OF A FACE

If you desire to acquire facility in keeping in your mind the expression of a face, first learn by heart the various different kinds of heads, eyes, noses, mouths, chins, throats, and also necks and shoulders. Take as an instance noses:—they are of ten types: straight, bulbous, hollow, prominent either above or below the centre, aquiline, regular, simian, round, and pointed. These divisions hold good as regards profile. Seen from in front, noses are of twelve types: thick in the middle, thin in the middle, with the tip broad, and narrow at the base, and narrow at the tip, and broad at the base, with nostrils broad or narrow, or high or low, and with the openings either visible or hidden by the tip. And similarly you will find variety in the other features; of which things you ought to make studies from nature and so fix them in your mind. Or when you have to draw a face from memory, carry with you a small notebook in which you have noted down such features, and then when you have cast a glance at the face of the person whom you wish to draw you can look privately and see which nose or mouth has a resemblance to it, and make a tiny mark against it in order to recognise it again at home. Of abnormal faces I here say nothing, for they are kept in mind without difficulty.

OF THE GAMES IN WHICH DRAUGHTSMEN SHOULD INDULGE

When you, draughtsmen, wish to find some profitable recreation in games you should always practise things which may be of use in your profession, that is by giving your eye accuracy of judgment so that it may know how to estimate the truth as to the length and breadth of objects. So in order to accustom the mind to such things let one of you draw a straight line anywhere on a wall; and then let each of you take a light rush or straw in his hand, and let each cut his own to the length which the first line appears to him when he is distant from it a space of ten braccia, and then let each go up to the copy in order to measure it against the length which he has judged it to be, and he whose measure comes nearest to the length of the copy has done best and is the winner, and he should receive from all the prize which was previously agreed upon by you. Furthermore you should take measurements fore-shortened, that is, you should take a spear or some other stick and look before you to a certain point of distance, and then let each set himself to reckon how many times this measure is contained in the said distance. Another thing is to see who can draw the best line one braccio in length, and this may be tested by tightly drawn thread.

Diversions such as these enable the eye to acquire accuracy of judgment, and this is the primary essential of painting.

WHETHER IT IS BETTER TO DRAW IN COMPANY OR NO

I say and am prepared to prove that it is much better to be in the company of others when you draw rather than alone, for many reasons. The first is that you will be ashamed of being seen in the ranks of the draughtsmen if you are outclassed by them, and this feeling of shame will cause you to make progress in study; secondly a rather commendable envy will stimulate you to join the number of those who are more praised than you are, for the praises of the others will serve you as a spur; yet another is that you will acquire something of the manner of anyone whose work is better than yours, while if you are better than the others you will profit by seeing how to avoid their errors, and the praises of others will tend to increase your powers.

MS. 2038 Bib. Nat. 26 v.

OF THE PROPER TIME FOR STUDYING THE SELECTION OF SUBJECTS

The winter evenings should be spent by youthful students in study of the things prepared during the summer; that is, all the drawings from the nude which you have made in the summer should be brought together, and you should make a choice from among them of the best limbs and bodies, and practise at these and learn them by heart.

OF ATTITUDES

Afterwards in the ensuing summer you should make choice of some one who has a good presence, and has not been brought up to wear doublets, and whose figure consequently has not lost its natural bearing, and make him go through various graceful and elegant movements. If he fails to show the muscles very clearly within the outlines of the limbs, this is of no consequence. It is enough for you merely to obtain good attitudes from the figure, and you can correct the limbs by those which you have studied during the winter.

HOW IT IS NECESSARY FOR THE PAINTER TO KNOW THE INNER STRUCTURE OF MAN

The painter who has acquired a knowledge of the nature of the sinews, muscles, and tendons will know exactly in the movement of any limb how many and which of the sinews are the cause of it, and which muscle by its swelling is the cause of this sinew's contracting, and which sinews having been changed into most delicate cartilage surround and contain the said muscle. So he will be able in divers ways and universally to indicate the various muscles by means of the different attitudes of his figures; and he will not do like many who in different actions always make the same things appear in the arm, the back, the breast, and the legs; for such things as these ought not to rank in the category of minor faults.

OF THE CHOICE OF BEAUTIFUL FACES

Methinks it is no small grace in a painter to be able to give a pleasing air to his figures, and whoever is not naturally possessed of this grace may acquire it by study, as opportunity offers, in the following manner. Be on the watch to take the best parts of many beautiful faces of which the beauty is established rather by general repute than by your own judgment, for you may readily deceive yourself by selecting such faces as bear a resemblance to your own, since it would often seem that such similarities please us; and if you were ugly you would not select beautiful faces, but would be creating ugly faces like many painters whose types often resemble their master; so therefore choose the beautiful ones as I have said, and fix them in your mind.

MS. 2038 Bib. Nat. 27 r.

OF THE LIFE OF THE PAINTER IN HIS STUDIO

The painter or draughtsman ought to be solitary, in order that the well-being of the body may not sap the vigour of the mind; and more especially when he is occupied with the consideration and investigation of things which by being continually present before his eyes furnish food to be treasured up in the memory.

If you are alone you belong entirely to yourself; if you are accompanied even by one companion you belong only half to yourself, or even less in proportion to the thoughtlessness of his conduct; and if you have more than one companion you will fall more deeply into the same plight.

If you should say, 'I will take my own course; I will retire apart, so that I may be the better able to investigate the forms of natural objects', then I say this must needs turn out badly, for you will not be able to prevent yourself from often lending an ear to their chatter; and not being able to serve two masters you will discharge badly the duty of companionship, and even worse that of endeavouring to realise your conceptions in art.

But suppose you say, 'I will withdraw so far apart that their words shall not reach me nor in any way disturb me'. I reply that in this case you will be looked upon as mad, and bear in mind that in so doing you will then be solitary.

If you must have companionship choose it from your studio; it may then help you to obtain the advantages which result from different methods of study. All other companionship may prove extremely harmful. MS. 2038 Bib. Nat. 27 v. and r.

Of the method of learning aright how to compose groups of figures in historical pictures:

When you have thoroughly learnt perspective, and have fixed in your memory all the various parts and forms of things, you should often amuse yourself when you take a walk for recreation, in watching and taking note of the attitudes and actions of men as they talk and dispute, or laugh or come to blows one with another, both their actions and those of the bystanders who either intervene or stand looking on at these things; noting these down with rapid strokes in this way,[1] in a little pocket-book, which you ought always to carry with you. And let this be of tinted paper, so that it may not be rubbed out; but you should change the old for a new one, for these are not things to be

[1] Sketch of figure in text of MS.

rubbed out but preserved with the utmost diligence; for there is such an infinite number of forms and actions of things that the memory is incapable of preserving them, and therefore you should keep those [sketches] as your patterns and teachers.

HOW ONE OUGHT FIRST TO LEARN DILIGENCE RATHER THAN RAPID EXECUTION

If as draughtsman you wish to study well and profitably, accustom yourself when you are drawing to work slowly, and to determine between the various lights, which possess the highest degree and measure of brightness, and similarly as to the shadows, which are those that are darker than the rest, and in what manner they mingle together, and to compare their dimensions one with another; and so with the contours to observe which way they are tending, and as to the lines what part of each is curved in one way or another, and where they are more or less conspicuous and consequently thick or fine; and lastly to see that your shadows and lights may blend without strokes or lines in the manner of smoke. And when you shall have trained your hand and judgment with this degree of care it will speedily come to pass that you will have no need to take thought thereto.

MS. 2038 Bib. Nat. 27 v.

OF JUDGING YOUR OWN PICTURE

We know well that mistakes are more easily detected in the works of others than in one's own, and that oftentimes while censuring the small faults of others you will overlook your own great faults. In order to avoid such ignorance make yourself first of all a master of perspective, then gain a complete knowledge of the proportions of man and other animals, and also make yourself a good architect, that is in so far as concerns the form of the buildings and of the other things which are upon the earth, which are infinite in form; and the more knowledge you have of these the more will your work be worthy of praise; and for those things in which you have no practice do not disdain to draw from nature. But to return to what has been promised above, I say that when you are painting you should take a flat mirror and often look at your work within it, and it will then be seen in reverse, and will appear to be by the hand of some other master, and you will be better able to judge of its faults than in any other way.

It is also a good plan every now and then to go away and have a little relaxation; for then when you come back to the work your judgment will be surer, since to remain constantly at work will cause you to lose the power of judgment.

It is also advisable to go some distance away, because then the work appears smaller, and more of it is taken in at a glance, and a lack of harmony or proportion in the various parts and in the colours of the objects is more readily seen.

THIS RULE OUGHT TO BE GIVEN TO CHILDREN WHO PAINT

We know clearly that the sight is one of the swiftest actions that can exist, for in the same instant it surveys an infinite number of forms; nevertheless it can only comprehend one thing at a time. To take an instance: you, O Reader, might at a glance look at the whole of this written page, and you would instantly decide that it is full of various letters, but you will not recognise in this space of time either what letters they are or what they purport to say, and therefore it is necessary for you if you wish to gain a knowledge of these letters to take them word by word and line by line.

Again, if you wish to go up to the summit of a building it will be necessary for you to ascend step by step, otherwise it will be impossible to reach the top. So I say to you whom nature inclines to this art that if you would have a true knowledge of the forms of different objects you should commence with their details, and not pass on to the second until the first is well in your memory and you have practised it. If you do otherwise you will be throwing away time, and to a certainty you will greatly prolong the period of study. And remember to acquire diligence rather than facility. MS. 2038 Bib. Nat. 28 r.

OF THE CONFORMITY OF THE LIMBS

Further I remind you to pay great attention in giving limbs to your figures, so that they may not merely appear to harmonize with the size of the body but also with its age. So the limbs of youths should have few muscles and veins, and have a soft surface and be rounded and pleasing in colour; in men they should be sinewy and full of muscles; in old men the surface should be wrinkled, and rough, and covered with veins, and with the sinews greatly protruding.

How little children have their joints the reverse of those of men in their thickness:

Little children have all the joints slender while the intervening parts are thick; and this is due to the fact that the joints are only covered by skin and there is no flesh at all over them, and this skin acts as a sinew to gird and bind together the bones; and a flabby layer of flesh is found between one joint and the next, shut in between the skin and the bone. But because the bones are thicker at the joints than between them, the flesh as the man grows up loses that superfluity which existed between the skin and the bone, and so the skin is drawn nearer to the bone and causes the limbs to seem more slender. But since there is nothing above the joints except cartilaginous and sinewy skin, this cannot dry up, and not being dried up it does not shrink. So for these reasons the limbs of children are slender at the joints and thick between the joints, as is seen in the joints of the fingers, arms, and shoulders which are slender and have great dimples; and a man on the contrary has all the joints of fingers, arms, and legs thick, and where children have hollows men have the joints protruding.

OF THE DIFFERENCE OF THE MEASUREMENTS IN BOYS AND MEN

I find a great difference between men and small boys in the length from one joint to another; for whereas the distance from the joint of the shoulder to the elbow, and from the elbow to the tip of the thumb, and from the humerus of one of the shoulders to the other, in a man is twice the head, in a child it is only once, because nature fashions the stature of the seat of the intellect for us before that of its active members.

OF THE RENDERING OF THE LIGHTS

Make first a general shadow over the whole of the extended part which does not see the light; then give to it the half shadows and the strong shadows, contrasting these one with another.

And similarly give the extended light in half-tone, adding afterwards the half-lights and the high lights and contrasting these in the same manner. MS. 2038 Bib. Nat. 28 v.

In what way you ought to make a head so that its parts may fit into their true positions:

To make a head so that its features are in agreement with those of a head that turns and bends, use these means: you know that the eyes, eyebrows, nostrils, corners of the mouth and sides of the chin, jaw, cheeks, ears and all the parts of a face are placed at regular positions upon the face, therefore when you have made the face, make lines which pass from one corner of the eye to the other; and so also for the position of each feature. Then having continued the ends of these lines beyond the two sides of the face, observe whether on the right and the left the spaces in the same parallel are equal. But I would specially remind you that you must make these lines extend to the point of your vision.

The way to represent the eighteen actions of man: [these are] rest, movement, speed; erect, leaning, seated, bending, kneeling, lying down, suspended; carrying, being carried, pushing, dragging, striking, being struck, pressing down and raising up.

You will treat first of the lights cast by windows to which you will give the name of restricted light; then treat of the lights of landscape to which you will give the name of free light; then treat of the light of luminous bodies.

HOW TO MAKE AN IMAGINARY ANIMAL APPEAR NATURAL

You know that you cannot make any animal without it having its limbs such that each bears some resemblance to that of some one of the other animals. If therefore you wish to make one of your imaginary animals appear natural—let us suppose it to be a dragon—take for its head that of a mastiff or setter, for its eyes those of a cat, for its ears those of a porcupine, for its nose that of a greyhound, with the eyebrows of a lion, the temples of an old cock and the neck of a water-tortoise.

OF DRAWING AN OBJECT

See that when you are drawing and make a beginning of a line, that you look over all the object that you are drawing for any detail whatever which lies in the direction of the line that you have begun.

MS. 2038 Bib. Nat. 29 r.

How a figure is not worthy of praise unless such action appears in it as serves to express the passion of the soul:

That figure is most worthy of praise which by its action best expresses the passion which animates it.

HOW ONE OUGHT TO REPRESENT AN ANGRY FIGURE

An angry figure should be represented seizing someone by the hair and twisting his head down to the ground, with one knee on his ribs, and with the right arm and fist raised high up; let him have his hair dishevelled, his eyebrows low and knit together, his teeth clenched, the two corners of his mouth arched, and the neck which is all swollen and extended as he bends over the foe, should be full of furrows.

HOW TO REPRESENT A MAN IN DESPAIR

A man who is in despair you should make turning his knife against himself, and rending his garments with his hands, and one of his hands should be in the act of tearing open his wound. Make him with his feet apart, his legs somewhat bent, and the whole body likewise bending to the ground, and with his hair torn and streaming.

OF THE GRACE OF THE LIMBS

The limbs should fit the body gracefully in harmony with the effect you wish the figure to produce; and if you desire to create a figure which shall possess a charm of its own, you should make it with limbs graceful and extended, without showing too many of the muscles, and the few which your purpose requires you to show indicate briefly, that is without giving them prominence, and with the shadows not sharply defined, and the limbs, and especially the arms, should be easy, that is that no limb should be in a straight line with the part that adjoins it. And if the hips which form as it were the poles of the man, are by his position placed so that the right is higher than the left, you should make the top shoulder-joint so that a line drawn from it perpendicularly falls on the most prominent part of the hip, and let this right shoulder be lower than the left.

And let the hollow of the throat always be exactly over the middle of the joint of the foot which is resting on the ground. The leg which does not support the weight should have its knee below the other and near to the other leg.

The positions of the head and arms are numberless, and therefore I will not attempt to give any rule; it will suffice that they should be natural and pleasing and should bend and turn in various ways, with the joints moving freely so that they may not seem like pieces of wood.

HOW THE CAST SHADOW IS NEVER EQUAL IN SIZE TO ITS CAUSE

If as experience shows luminous rays come from a single point, and proceed in the form of a sphere from this point radiating and spreading themselves through the air, the farther they go the more they are dispersed; and an object placed between the light and the wall is always reproduced larger in its shadow, because the rays that strike it have become larger by the time they have reached the wall.

MS. 2038 Bib. Nat. 29 v.

OF THE ARRANGEMENT OF THE LIMBS

As regards the arrangement of the limbs, you should bear in mind that when you wish to represent one who by some chance has either to turn backwards or on one side, you must not make him move his feet and all his limbs in the same direction as he turns his head; but you should show the process spreading itself and taking effect over the four sets of joints, namely those of the foot, the knee, the hip, and the neck. And if you let his weight rest on the right leg, you should make the knee of the left bend inwards; and the foot of it should be slightly raised on the outside, and the left shoulder should be somewhat lower than the right; and the nape of the neck should be exactly above the outer curve of the ankle of the left foot, and the left shoulder should be above the toe of the right foot in a perpendicular line. And always so dispose your figures that the direction in which the head is turned is not that in which the breast faces, since nature has for our convenience so formed the neck that it can easily serve the different occasions on which the eye desires to turn in various directions; and to this same organ the other joints are in part responsive. And if ever you show a man sitting with his hands at work upon something by his side, make the chest turn upon the hip joints.

OF THE SHADOW CAST BY A BODY SITUATED BETWEEN TWO EQUAL LIGHTS

A body which finds itself placed between two equal lights will put forth two shadows, which will take their direction equally according to the lines of the two lights. And if you move the body farther away or bring it nearer to one of the lights, the shadow which points to the nearer light will be less deep than that which points to the one more remote.

THE BODY NEARER TO THE LIGHT WILL CAST THE LARGER SHADOW, AND WHY

If an object placed in front of a particular light be very near to it you will see it cast a very large shadow on the opposite wall, and the farther you remove the object from the light the smaller will the shadow become.

WHY A SHADOW WHICH IS GREATER THAN ITS CAUSE WILL BE OUT OF PROPORTION

The want of proportion of the shadow which is greater than its cause, arises from the fact that as the light is less than its object it cannot be at an equal distance from the extremities of the object, and the part which is at a greater distance increases more than those which are nearer, and therefore the shadow increases.

WHY A SHADOW WHICH IS BIGGER THAN THE BODY THAT CAUSES IT HAS INDISTINCT CONTOURS

Atmosphere which surrounds a light almost partakes of the nature of this light in brightness and in warmth; the farther away it recedes the more it loses this resemblance. An object which casts a large shadow is near to the light and finds itself lit up both by the light and by the luminous atmosphere, and consequently this atmosphere leaves the contours of the shadow indistinct. MS. 2038 Bib. Nat. 30 r.

THE WAY TO REPRESENT A BATTLE

Show first the smoke of the artillery mingled in the air with the dust stirred up by the movement of the horses and of the combatants. This process you should express as follows: the dust, since it is made up of earth and has weight, although by reason of its fineness it may easily rise and mingle with the air, will nevertheless readily fall down again, and the greatest height will be attained by such part of it as is the finest, and this will in consequence be the least visible and will seem almost the colour of the air itself.

The smoke which is mingled with the dust-laden air will as it rises to a certain height have more and more the appearance of a dark cloud, at the summit of which the smoke will be more distinctly visible than the dust. The smoke will assume a bluish tinge, and the dust will keep its natural colour. From the side whence the light comes this mixture of air and smoke and dust will seem far brighter than on the opposite side.

As for the combatants the more they are in the midst of this turmoil the less they will be visible, and the less will be the contrast between their lights and shadows.

You should give a ruddy glow to the faces and the figures and the air around them, and to the gunners and those near to them, and this glow should grow fainter as it is farther away from its cause. The figures which are between you and the light, if far away, will appear dark against a light background, and the nearer their limbs are to the ground the less will they be visible, for there the dust is greater and thicker. And if you make horses galloping away from the throng, make little clouds of dust as far distant one from another as is the space between the strides made by the horse, and that cloud which is farthest away from the horse should be the least visible, for it should be high and spread out and thin, while that which is nearest should be most conspicuous and smallest and most compact.

Let the air be full of arrows going in various directions, some mounting upwards, others falling, others flying horizontally; and let the balls shot from the guns have a train of smoke following their course. Show the figures in the foreground covered with dust on their hair and eyebrows and such other level parts as afford the dust a space to lodge.

Make the conquerors running, with their hair and other light things streaming in the wind, and with brows bent down; and they should be thrusting forward opposite limbs, that is, if a man advances the right foot, the left arm should also come forward. If you represent anyone fallen you should show the mark where he has been dragged through the dust which has become changed to blood-stained mire, and round about in the half-liquid earth you should show the marks of the trampling of men and horses who have passed over it.

Make a horse dragging the dead body of his master, and leaving behind him in the dust and mud the track of where the body was dragged along.

Make the beaten and conquered pallid, with brows raised and knit together, and let the skin above the brows be all full of lines of pain; at the sides of the nose show the furrows going in an arch from the nostrils and ending where the eye begins, and show the dilatation of the nostrils which is the cause of these lines; and let the lips be arched displaying the upper row of teeth, and let the teeth be parted after the manner of such as cry in lamentation. Show someone using his hand as a shield for his terrified eyes, turning the palm of it towards the enemy, and having the other resting on the ground to support the weight of his body; let others be crying out with their mouths wide open, and fleeing away. Put all sorts of armour lying between the feet of the combatants, such as broken shields, lances, swords, and other things like these. Make the dead, some half-buried in dust, others with the dust all mingled with the oozing blood and changing into crimson mud; and let the line of the blood be discerned by its colour, flowing in a sinuous stream from the corpse to the dust. Show others in the death agony grinding their teeth and rolling their eyes, with clenched fists grinding against their bodies and with legs distorted. Then you might show one, disarmed and struck down by the enemy, turning on him with teeth and nails to take fierce and inhuman vengeance; and let a riderless horse be seen galloping with mane streaming in the wind, charging among the enemy and doing them great mischief with his hoofs.

You may see there one of the combatants, maimed and fallen on the ground, protecting himself with his shield, and the enemy bending down over him and striving to give him the fatal stroke; there might also be seen many men fallen in a heap on top of a dead horse; and you should show some of the victors leaving the combat and retiring apart from the crowd, and with both hands wiping away from eyes and cheeks the thick layer of mud caused by the smarting of their eyes from the dust.[1]

And the squadrons of the reserves should be seen standing full of hope but cautious, with eyebrows raised, and shading their eyes with their hands, peering into the thick, heavy mist in readiness for the commands of their captain; and so too the captain with his staff raised, hurrying to the reserves and pointing out to them the quarter of the field where they are needed; and you should show a river, within which horses are galloping, stirring the water all around with a heaving mass of waves and foam and broken water, leaping high into the air and over the legs and bodies of the horses; but see that you make no level spot of ground that is not trampled over with blood.

MS. 2038 Bib. Nat. 31 r. and 30 v.

HOW HIGH THE POINT OF SIGHT SHOULD BE PLACED

This point ought to be at the same level as the eye of an ordinary man; and the end of the flat country which borders upon the sky should be made of the same height as the line where the earth touches the horizon, except for the mountains which are in liberty.

MS. 2038 Bib. Nat. 31 r.

[1] MS. has *per lamor della polvere.*

HOW SMALL FIGURES OUGHT CONSEQUENTLY TO BE LEFT UNFINISHED

I say that when objects appear of minute size, it is due to the said objects being at a distance from the eye; and when this is the case, there must of necessity be a considerable quantity of atmosphere between the eye and the object, and this atmosphere interferes with the distinctness of the form of the objects, and consequently the minute details of these bodies will become indistinguishable and unrecognisable.

Therefore, O painter, you should make your lesser figures only suggested, and not highly finished; for if you do otherwise, you will produce effects contrary to those of nature, your mistress.

The object is small because of the great space which exists between the eye and it. This great space contains within itself a great quantity of atmosphere; and this atmosphere forms of itself a dense body which interposes and shuts out from the eye the minute details of the objects.

WHAT BACKGROUND A PAINTER SHOULD CHOOSE FOR HIS WORKS

Since one sees by experience that all bodies are surrounded by shadow and light it is expedient, O painter, that you so dispose the part illuminated that it is outlined against a dark object, and that in the same way the part of the body in shadow is outlined against a bright object. And this rule will be a great help to you in giving relief to your figures.

OF DRAWING

When you have to draw from nature stand three times as far away as the size of the object that you are drawing.

Why does a painting seem better in a mirror than outside it?

HOW IN ALL TRAVELS ONE MAY LEARN

This benign nature so provides that over all the world you find something to imitate.

OF SHADOW

Where the shadow is bounded by light, note carefully where it is lighter or darker, and where it is more or less indistinct towards the light; and above all I would remind you that in youthful figures you should not make the shadows end like stone, for the flesh retains a slight transparency, as may be observed by looking at a hand held between the eye and the sun, when it is seen to flush red and to be of a luminous transparency.

And let the part which is brightest in colour be between the lights and the shadows. And if you wish to see what depth of shadow is needed for the flesh, cast a shadow over it with your finger, and according as you wish it to be lighter or darker, hold your finger nearer or farther away from the picture, and then copy this shadow.

OF HOW TO DEPICT A WILD LANDSCAPE

Those trees and shrubs which are more split up into a quantity of thin branches ought to have less density of shadow. The trees and the shrubs which have larger leaves cast a greater shadow.

MS. 2038 Bib. Nat. 31 v.

HOW ONE OUGHT TO ARRANGE THE LIGHT UPON FIGURES

The disposition of the light should be in harmony with the natural conditions under which you represent your figure; that is, if you are representing it in sunlight, make the shadows dark with great spaces of light, and mark the shadows of all the surrounding bodies and their shadows upon the ground. If you represent it in dull weather, make only a slight difference between the lights and the shadows, and do not make any other shadow at the feet. If you represent it within doors, make a strong difference between the lights and shadows and show the shadow on the ground, and if you represent a window covered by a curtain and the wall white there should be little difference between the lights and shadows. If it is lit by a fire you should make the lights ruddy and powerful and the shadows dark; and the shadows should be sharply defined where they strike the walls or the floor, and the farther away they extend from the body the broader and larger should they become. And if it be lit in part by the fire and in part by the atmosphere, make the part lit by the atmosphere the stronger, and let that lit by the fire be almost as red as fire itself. And above all let the figures that you paint have sufficient light and from above, that is all living persons whom you paint, for the people whom you see in the streets are all lighted from above; and I would have you know that you have no acquaintance so intimate but that if the light fell on him from below you would find it difficult to recognise him.

THE ORDER OF LEARNING TO DRAW

First of all copy drawings by a good master made by his art from nature and not as exercises; then from a relief, keeping by you a drawing done from the same relief; then from a good model; and of this you ought to make a practice.

AT WHAT HEIGHT THE LIGHT SHOULD BE IN ORDER TO DRAW FROM NATURE

When you are drawing from nature the light should be from the north, so that it may not vary; and if it is from the south keep the window covered with a curtain so that though the sun shine upon it all day long the light will undergo no change. The elevation of the light should be such that each body casts a shadow on the ground which is of the same length as its height.

WHY BEAUTIFUL COLOURS SHOULD BE IN THE LIGHTS

Since we see that the quality of colours becomes known by means of light, it is to be inferred that where there is most light there the true quality of the colour so illuminated will be most visible, and where there is most shadow there the colour will be most affected by the colour of the shadow. Therefore, O painter, be mindful to show the true quality of the colours in the parts which are in light.

MS. 2038 Bib. Nat. 33 r.

OF LIGHT AND SHADE

Each part of the surface of a body is in part affected by the colour of the thing opposite to it.

Example

If you set a spherical body in the midst of different objects, that is, so that on the one side it has the light of the sun and on the side opposite there is a wall illuminated by the sun, which may be green or some other colour, the surface on which it is resting being red and the two transverse sides dark, you will see the natural colour of this object take on the hues of those colours which are over against it. The strongest will be that proceeding from the light, the second that from the illuminated wall, the third that of the shadow. There yet remains however a portion which will take its hue from the colour of the edges.

The supreme misfortune is when theory outstrips performance.

In the choice of figures aim at softness and delicacy rather than that they should be stiff and wooden.

HOW THE CONDITION OF THE ATMOSPHERE AFFECTS THE LIGHTS AND SHADOWS

That body will present the strongest contrast between its lights and shadows which is seen by the strongest light, such as the light of the sun or at night by the light of a fire; but this should rarely be employed in painting, because the work will remain hard and devoid of grace.

A body which is in a moderate light will have but little difference between its lights and shadows; and this comes to pass at the fall of the evening, or when there are clouds: works painted then are soft in feeling and every kind of face acquires a charm.

Thus in every way extremes are injurious. Excess of light makes things seem hard;[1] and too much darkness does not admit of our seeing them. The mean is excellent.

[1] MS. has *il tropo lume fa crudo.* So also Dr. Richter. The text of M. Ravaisson-Mollien has *facendo* in place of *fa crudo.*

OF SMALL LIGHTS

The lights cast from small windows also present a strong contrast of light and shadow, more especially if the chamber lit by them is large; and this is not good to use in painting.

MS. 2038 Bib. Nat. 33 v.

The painter who draws by practice and judgment of the eye without the use of reason, is like the mirror that reproduces within itself all the objects which are set opposite to it without knowledge of the same.

C.A. 76 r. a

That countenance which in a picture is looking full in the face of the master who makes it will always be looking at all the spectators. And the figure painted when seen below from above will always appear as though seen below from above, although the eye of the beholder may be lower than the picture itself. C.A. 111 v. b

OF THE PARTS OF THE FACE

If nature had only one fixed standard for the proportions of the various parts, then the faces of all men would resemble each other to such a degree that it would be impossible to distinguish one from another; but she has varied the five parts of the face in such a way that although she has made an almost universal standard as to their size, she has not observed it in the various conditions to such a degree as to prevent one from being clearly distinguished from another.

C.A. 119 v. a

As the body with great slowness produced by the length of its contrary movement turns in greater space and thereby gives a stouter blow, whereas movements which are continuous and short have little strength—so study upon the same subject made at long intervals of time causes the judgment to become more perfect and the better to recognise its own mistakes. And the same is true of the eye of the painter as it draws farther away from his picture. C.A. 122 v. a

A picture or any representation of figures ought to be done in such a way that those who see them may be able with ease to recognise from their attitudes what is passing through their minds. So if you have to represent a man of good repute in the act of speaking, make his gestures accord with the probity of his speech; and similarly if you have to represent a brutal man, make him with fierce movements flinging out his arms towards his hearer, and the head and chest protruding forward beyond the feet should seem to accompany the hands of the speaker.

Just so a deaf mute who sees two people talking, although being himself deprived of the power of hearing, is none the less able to divine from the movements and gestures of the speakers the subject of their discussion.

I once saw in Florence a man who had become deaf, who could not understand you if you spoke to him loudly, while if you spoke softly without letting the voice utter any sound, he understood you merely from the movement of the lips. Perhaps, however, you will say to me: 'But does not a man who speaks loudly move his lips like one who speaks softly? And since the one moves his lips like the other, will not the one be understood like the other?' As to this I leave the decision to the test of experience. Set someone to speak softly and then [louder], and watch the lips. C.A. 139 r. d

How from age to age the art of painting continually declines and deteriorates when painters have no other standard than work already done:

The painter will produce pictures of little merit if he takes the works of others as his standard; but if he will apply himself to learn from the objects of nature he will produce good results. This we see was the case with the painters who came after the time of the Romans, for they continually imitated each other, and from age to age their art steadily declined.

After these came Giotto the Florentine, and he—reared in mountain solitudes, inhabited only by goats and such like beasts—turning straight from nature to his art, began to draw on the rocks the movements of the goats which he was tending, and so began to draw the figures of all the animals which were to be found in the country, in such a way that after much study he not only surpassed the masters of his own time but all those of many preceding centuries. After him art again declined, because all were imitating paintings already done; and so for centuries it continued to decline until such time as Tommaso the Florentine, nick-named Masaccio, showed by the perfection of his work how those who took as their standard anything other than nature, the supreme guide of all the masters, were wearying themselves in vain. Similarly I would say about these mathematical subjects, that those who study only the authorities and not the works of nature are in art the grandsons and not the sons of nature, which is the supreme guide of the good authorities.

Mark the supreme folly of those who censure such as learn from nature, leaving uncensured the authorities who were themselves the disciples of this same nature! C.A. 141 r. b

OF COMPOSING HISTORICAL SUBJECTS

Of not regarding the limbs of the figures in historical subjects, as many do who in making whole figures spoil their arrangement. For when you make figures one behind another, see that you draw them in their entirety, so that the limbs which are seen appearing beyond the surface of the first figure may retain their natural length and position. C.A. 160 r. a

When a man running wishes to use up the impetus which is carrying him on, he prepares a contrary impetus which is brought into operation by his leaning backwards; this is capable of proof, for if the impetus carries the moving body forward with a momentum represented by four, and the impulse of the moving body to turn and fall back has a momentum of four the one momentum will neutralise the other which is contrary to it, and so the impetus is used up.

PAINTING

The surface of each body takes part of the colour of whatever is set against it. The colours of the objects in light are reproduced on each other's surface at different spots according to the varieties in the positions of these objects. [*Diagram*] Let *o* be a blue object in light, which alone by itself faces the space *b c* of the white sphere *a b c d e f*, and tinges it blue; and let *m* be a yellow object which is reflected on the space *a b* in company with the blue object *o*, and tinges it green, by the second of this which shows that blue and yellow together produce a most beautiful green, etc.—and the rest will be set forth in the Book on Painting. In that book it will be demonstrated, by transmitting the images of the bodies and colours of the things illuminated by the sun through a small round hole in a dark place on to a smooth surface which in itself is white. But everything will be upside down.

C.A. 181 r. a

THE LIFE OF THE PAINTER IN THE COUNTRY

The painter requires such knowledge of mathematics as belongs to painting, and severance from companions who are not in sympathy with his studies, and his brain should have the power of adapting itself to the tenor of the objects which present themselves before it, and he should be freed from all other cares.

And if while considering and examining one subject a second should intervene, as happens when an object occupies the mind, he ought to decide which of these subjects presents greater difficulties in investigation, and follow that until it becomes entirely clear, and afterwards pursue the investigation of the other. And above all he should keep his mind as clear as the surface of a mirror, which becomes changed to as many different colours as are those of the objects within it, and his companions should resemble him in a taste for these studies, and if he fail to find any such he should accustom himself to be alone in his investigations, for in the end he will find no more profitable companionship. C.A. 184 v. c

OF THE ORDER TO BE OBSERVED IN STUDY

I say that one ought first to learn about the limbs and how they are worked, and after having completed this knowledge one ought to study their actions in the different conditions in which men are placed, and thirdly to devise figure compositions, the studies for these being taken from natural actions made on occasion as opportunities offered; and one should be on the watch in the streets and squares and fields, and there make sketches with rapid strokes to represent features, that is for a head one may make an *o*, and for an arm a straight or curved line, and so in like manner for the legs and trunk, afterwards when back at home working up these notes in a completed form.

My opponent says that in order to gain experience and to learn how to work readily, it is better that the first period of study should be spent in copying various compositions made by different masters either on sheets of paper or on walls, since from these one acquires rapidity in execution and a good method. But to this it may be replied that the ensuing method would be good if it was founded upon works that were excellent in composition and by diligent masters; and since such masters are so rare that few are to be found, it is safer to go direct to the works of nature than to those which have been imitated from her originals with great deterioration and thereby to acquire a bad method, for he who has access to the fountain does not go to the water-pot.

C.A. 199 V. a

These rules are to be used solely in testing figures; for every man in his first compositions makes certain mistakes, and if he does not become conscious of them he does not correct them; therefore in order to discover mistakes you should test your work and where you find there mistakes correct them, and remember never to fall into them again. But if you were to attempt to apply all these rules in composition you would never make a beginning and would cause confusion in your work.

These rules are intended to help you to a free and good judgment; for good judgment proceeds from good understanding, and good understanding comes from reason trained by good rules, and good rules are the children of sound experience, which is the common mother of all the sciences, and arts. If therefore you bear well in mind the precepts of my rules you will be able merely by the accuracy of your judgment to criticize and discern every error in proportion in any work, whether it is in the perspective or in the figures or other things. C.A. 221 V. d

All the limbs of every kind of animal should correspond with its age, that is, the young should not show their veins or nerves as most [painters] do in order to show their dexterity in art, spoiling the whole by mistakes in the limbs.

All the parts of an animal should correspond with the whole, that is, when a man is short and thickset you must see that each of his limbs is short and thickset.

Let the movements of men be such as are in keeping with their dignity or meanness. C.A. 345 v. b

Make your work to be in keeping with your purpose and design; that is, when you make your figure you should consider carefully who it is and what you wish it to be doing.

In order to produce an effect of similar action in a picture of an old man and a young, you must make the action of the young man appear more vigorous in proportion as he is more powerful than the old man, and you will make the same difference between a young man and an infant.

If you have to represent a man either as moving or lifting or pulling, or carrying a weight equal to his own weight, how ought you to fit the legs under his body? C.A. 349 r. b

Painters oftentimes deceive themselves by representing water in which they render visible what is seen by man; whereas the water sees the object from one side and the man sees it from the other; and it frequently happens that the painter will see a thing from above and the water sees it from beneath, and so the same body is seen in front and behind, and above and below, for the water reflects the image of the object in one way and the eye sees it in another. C.A. 354 r. d

We consider as a monstrosity one who has a very large head and short legs, and as a monstrosity also one who is in great poverty and has rich garments; we should therefore deem him well proportioned in whom the parts are in harmony with the whole. C.A. 375 r. c

OF THE ERROR WHICH IS COMMITTED IN JUDGING AS TO THE LIMBS

The painter who has clumsy hands will reproduce the same in his works, and the same thing will happen with every limb unless long study prevents it. Do you then, O painter, take careful note of that part in yourself which is most mis-shapen, and apply yourself by study to remedy this entirely. For if you are brutal, your figures will be the same and devoid of grace, and in like manner every quality that there is within you of good or of evil will be in part revealed in your figures.

A 23 r.

When you draw nudes be careful always to draw the whole figure, and then finish the limb which seems the best and at the same time study its relation to the other limbs, as otherwise you may form the habit of never properly joining the limbs together.

Take care never to make the head turn the same way as the chest nor the arm move with the leg; and if the head is turned towards the right shoulder make all the parts lower on the left side than on the right, but if you make the chest prominent and the head turning on the left side, then make the parts on the right side higher than those on the left. A 28 v.

Note in the movements and attitudes of the figures how the limbs and their expressions vary, because the shoulder blades in the movements of the arms and shoulders alter considerably the position of the backbone; and you will find all the causes of this in my book of Anatomy.

OF SHADOWS AND LIGHTS

You, who reproduce the works of nature, behold the dimensions, the degrees of intensity, and the forms of the lights and shadows of each muscle, and observe in the lengths of their figures towards which muscle they are directed by the axis of their central lines. E 3 r.

OF THE BACKGROUND OF THE FIGURES IN PAINTING

The background that surrounds the figures in any subject composition ought to be darker than the illuminated part of these figures, and lighter than their part in shadow. E 4 r.

That every part of a whole should be in proportion to its whole: thus if a man has a thick short figure that he should be the same in every one of his limbs, that is, with short thick arms, big hands, fingers thick and short, with joints of the same character and so with the rest.

And I would have the same understood to apply to all kinds of animals and plants; thus, in diminishing the parts, do so in proportion to their size, as also in enlarging.

OF HOW TO PAINT WIND

In representing wind, in addition to showing the bending of the boughs and the inverting of their leaves at the approach of the wind, you should represent the clouds of fine dust mingled with the troubled air. E 6 v.

OF THE REQUISITES OF PAINTING

The first requisite of painting is that the bodies which it represents should appear in relief, and that the scenes which surround them with effects of distance should seem to enter into the plane in which the picture is produced by means of the three parts of perspective, namely the diminution in the distinctness of the form of bodies, the diminution in their size, and the diminution in their colour. Of these three divisions of perspective, the first has its origin in the eye, the two others are derived from the atmosphere that is interposed between the eye and the objects which the eye beholds.

The second requisite of painting is that the actions should be appropriate and have a variety in the figures, so that the men may not all look as though they were brothers. E 79 v.

OF VARIETY IN FIGURES

The painter ought to strive at being universal, for there is a great lack of dignity in doing one thing well and another badly, like many who study only the measurements and proportions of the nude figure and do not seek after its variety; for a man may be properly proportioned and yet be fat and short or long and thin, or medium. And whoever does not take count of these varieties will always make his figures in one mould, so that they will all appear sisters, and this practice deserves severe censure.

OF THE ORDER OF ACQUIRING THIS UNIVERSALITY

It is an easy matter for whoever knows how to represent man to afterwards acquire this universality, for all the animals which live upon the earth resemble each other in their limbs, that is in muscles, sinews and bones, and they do not vary at all, except in length or thickness as will be shown in the Anatomy. There are also the aquatic animals, of which there are many different kinds; but with regard to these I do not advise the painter to make a fixed standard, for they are of almost infinite variety; and the same is also true of the insect world. G 5 V.

REPRESENTATION OF A DELUGE

The air was dark from the heavy rain which was falling slantwise, bent by the cross-current of the winds, and formed itself in waves in the air, like those one sees formed by the dust, the only difference being that these drifts were furrowed by the lines made by the drops of the falling water. It was tinged by the colour of the fire produced by the thunder-bolts wherewith the clouds were rent and torn asunder, the flashes from which smote and tore open the vast waters of the flooded valleys, and as these lay open there were revealed their depths[1] the bowed tops of the trees.

Neptune might be seen with his trident in the midst of the waters, and Æolus with his winds should be shown entangling the floating trees which had been uprooted and were mingled with the mighty waves.

The horizon and the whole firmament was overcast and lurid with the flashings of the incessant lightning.

Men and birds might be seen crowded together upon the tall trees which over-topped the swollen waters, forming hills which surround the great abysses. G 6 V.

[1] Dr. Richter reads *vertici*. I have followed M. Ravaisson-Mollien in reading *ventri*. MS. has *vertri*.

OF THE ERROR MADE BY THOSE WHO PRACTISE WITHOUT SCIENCE [1]

Those who are enamoured of practice without science are like a pilot who goes into a ship without rudder or compass and never has any certainty where he is going.

Practice should always be based upon a sound knowledge of theory, of which perspective is the guide and gateway, and without it nothing can be done well in any kind of painting. G 8 r.

Of the lights on the lower extremities of bodies packed tightly together, such as men in battle:

Of men and horses labouring in battle, the different parts should be darker in proportion as they are closer to the ground on which they are supported; and this is proved from the sides of wells, which become darker in proportion to their depth, this being due to the fact that the lowest part of the well sees and is seen by a lesser amount of the luminous atmosphere than any other part of it. And the pavements when they are the same colour as the legs of the men and horses will always seem in higher light within equal angles than will these same legs. G 15 r.

HOW TO PASS JUDGMENT UPON A PAINTER'S WORK

First you should consider the figures whether they have the relief which their position requires, and the light that illuminates them, so that the shadows may not be the same at the extremities of the composition as in the centre, because it is one thing for a figure to be surrounded by shadows, and another for it to have the shadows only on one side. Those figures are surrounded by shadows which are towards the centre of the composition, because they are shaded by the dark figures interposed between them and the light; and those are shaded on one side only which are interposed between the light and the main group, for where they do not face the light they face the group, and there they reproduce the darkness cast by this group, and where they do not face the group they face the brightness of the light, and there they reproduce its radiance.

[1] At margin of MS., 'See first the [Ars] Poetica of Horace'.

Secondly, you should consider whether the distribution or arrangement of the figures is devised in agreement with the conditions you desire the action to represent.

Thirdly, whether the figures are actively engaged on their purpose.

G 19 r.

OF PAINTING

A very important part of painting consists in the backgrounds of the things painted. Against these backgrounds the contour lines of such natural bodies as possess convex curves will always reveal the shapes of these bodies, even though the colours of the bodies are of the same hue as the background.

This arises from the fact of the convex boundaries of the objects not being illuminated in the same manner as the background is by the same light, because frequently the contours are clearer or darker than the background.

Should however these contours be of the same colour as the background, then undoubtedly this part of the picture will interfere with the perception of the figure formed by these contour lines. Such a predicament in painting ought to be avoided by the judgment of good painters, since the painter's intention is to make his bodies appear detached from the background; and in the above-mentioned instance the contrary occurs, not only in the painting but in the objects in relief. G 23 v.

AN INDICATION WHETHER A YOUTH HAS AN APTITUDE FOR PAINTING

There are many men who have a desire and love for drawing but no aptitude for it, and this can be discerned in children if they are not diligent and never finish their copies with shading.

The painter is not worthy of praise who does only one thing well, as the nude, or a head, or draperies, or animal life, or landscapes, or such other special subject; for there is no one so dull of understanding that after devoting himself to one subject only and continually practising at this, he will fail to do it well. G 25 r.

[*The representation of things in movement*]

Of the imitation of things which though they have movement in their own place, do not in this movement reveal themselves as they are in reality.

Drops of water when it rains, a winder, the turning-wheel, stones under the action of water, firebrands whirled round in a circle, proceed continuously, among things which are not in continuous movement.

G 35 r.

THE BOUNDARIES OF BODIES ARE THE LEAST OF ALL THINGS

The truth of this proposition is proved by the fact that the boundary of the substance is a surface, which is neither a part of the body enclosed by this surface nor a part of the atmosphere which surrounds this body, but is the medium interposed between the atmosphere and the body, as is proved in its place.

But the lateral boundaries of these bodies are the boundary line of the surface, which line is of invisible thickness. Therefore, O painter, do not surround your bodies with lines, and especially when making objects less than their natural size, for these not only cannot show their lateral boundaries, but their parts will be invisible, from distance.

G 37 r.

OF PAINTING

The high lights or the lustre of any particular object will not be situated in the centre of the illuminated part, but will make as many changes of position as the eye that beholds it. H 90 [42] v.

Painters have a good opportunity of observing actions in players, especially at ball or tennis or with the mallet when they are contending together, better indeed than in any other place or exercise. I 48 v.

It is the extremities of all things which impart to them grace or lack of grace. I 92 [44] v.

Men and words are actual, and you, painter, if you do not know how to execute your figures, will be like an orator who does not know how to use his words. K 110 [30] v.

It is a necessary thing for the painter, in order to be able to fashion the limbs correctly in the positions and actions which they can represent in the nude, to know the anatomy of the sinews, bones, muscles and tendons in order to know, in the various different movements and impulses, which sinew or muscle is the cause of each movement, and to make only these prominent and thickened, and not the others all over the limb, as do many who in order to appear great draughtsmen make their nudes wooden and without grace, so that it seems rather as if you were looking at a sack of nuts than a human form or at a bundle of radishes rather than the muscles of nudes. L 79 r.

In all things seen one has to consider three things, namely the position of the eye that sees, the position of the object seen and the position of the light that illumines this body. M 80 r.

[*With sketch*]

In the last folds of the joints of any limb everything which was in relief becomes a hollow, and similarly every hollow in the last of the said folds is changed into a protuberance when the end of the limb is straightened.

He who has not knowledge of this, often makes very great mistakes through relying too much upon his own skill, and not having recourse to the imitation of nature. And such variation is found more in the middle of the sides than in front and more behind than at the sides.

B.M. 44 r.

The painter contends with and rivals nature. Forster III 44 v.

[*On draperies*]

Variety in the subjects. The draperies thin, thick, new, old, with folds broken and pleated, *cride dolci* [?soft lights], shadows obscure and less obscure, either with or without reflections, definite or indistinct according to the distances and the various colours; and garments according to the rank of those who are wearing them, long and short, fluttering or stiff in conformity with the movements; so encircling the figures as to bend or flutter with ends streaming upwards or downwards according to the folds, clinging close about the feet or separated from them, according as the legs are shown at rest or bending or twisting or striking together within; either fitting closely or separating from the joints, according to the step or movement or whether the wind is represented.

And the folds should correspond to the quality of the draperies whether transparent or opaque.

[*Repetition—the greatest defect in a painter*]

The greatest defect in a painter is to repeat the same attitudes and the same expressions . . . in one . . .

[*On draperies*]

On the thin clothes of the women in walking, running and jumping, and their variety.

[*Notes on painting*]

And in painting make a discourse on the clothes and other raiments.

And you, O painter, who desire to perform great things, know that unless you first learn to do them well and with good foundations, the work that you do will bring you very little honour and less gain, but if you do it well it will produce you plenty of honour and be of great utility.

Quaderni IV 15 r.

When the subject of your picture is a history make two points, one of the eye and the other of the light, and make the latter as far distant as possible.

Windsor: Drawings 12604 r.

Nature of movements in man. Do not repeat the same actions in the limbs of men unless the necessity of their action constrains you.

Windsor: Drawings 19149 v.

OF A DELUGE AND THE REPRESENTATION OF IT IN PAINTING

Let the dark, gloomy air be seen beaten by the rush of opposing winds wreathed in perpetual rain mingled with hail,[1] and bearing hither and thither a vast network of the torn branches of trees mixed together with an infinite number of leaves. All around let there be seen ancient trees uprooted and torn in pieces by the fury of the winds. You should show how fragments of mountains, which have been already stripped bare by the rushing torrents, fall headlong into these very torrents and choke up the valleys, until the pent-up rivers rise in flood and

[1] MS. *gravza*. I have followed Dr. Richter's suggestion *gragnuola*.

cover the wide plains and their inhabitants. Again there might be seen huddled together on the tops of many of the mountains many different sorts of animals, terrified and subdued at last to a state of tameness, in company with men and women who had fled there with their children. And the fields which were covered with water had their waves covered over in great part with tables, bedsteads, boats and various other kinds of rafts, improvised through necessity and fear of death, upon which were men and women with their children, massed together and uttering various cries and lamentations, dismayed by the fury of the winds which were causing the waters to roll over and over in mighty hurricane, bearing with them the bodies of the drowned; and there was no object that floated on the water but was covered with various different animals who had made truce and stood huddled together in terror, among them being wolves, foxes, snakes and creatures of every kind, fugitives from death. And all the waves that beat against their sides were striking them with repeated blows from the various bodies of the drowned, and the blows were killing those in whom life remained.

Some groups of men you might have seen with weapons in their hands defending the tiny footholds that remained to them from the lions and wolves and beasts of prey which sought safety there. Ah, what dreadful tumults one heard resounding through the gloomy air, smitten by the fury of the thunder and the lightning it flashed forth, which sped through it, bearing ruin, striking down whatever withstood its course! Ah, how many might you have seen stopping their ears with their hands in order to shut out the loud uproar caused through the darkened air by the fury of the winds mingled together with the rain, the thunder of the heavens and the raging of the thunderbolts! Others were not content to shut their eyes, but placing their hands over them, one above the other, would cover them more tightly in order not to see the pitiless slaughter made of the human race by the wrath of God.

Ah me, how many lamentations! How many in their terror flung themselves down from the rocks! You might have seen huge branches of the giant oaks laden with men borne along through the air by the fury of the impetuous winds. How many boats were capsized and lying, some whole, others broken in pieces, on the top of men struggling to escape with acts and gestures of despair which foretold an awful death. Others with frenzied acts were taking their own lives, in despair of ever being able to endure such anguish; some of these were flinging themselves down from the lofty rocks, others strangled themselves with their own hands; some seized hold of their own children, and with mighty violence slew them at one blow; some turned their arms against themselves to wound and slay; others falling upon their knees were commending themselves to God.

Alas! how many mothers were bewailing their drowned sons, holding them upon their knees, lifting up open arms to heaven, and with divers cries and shrieks declaiming against the anger of the gods! Others with hands clenched and fingers locked together gnawed and devoured them with bites that ran blood, crouching down so that their breasts touched their knees in their intense and intolerable agony.

Herds of animals, such as horses, oxen, goats, sheep, were to be seen already hemmed in by the waters and left isolated upon the high peaks of the mountains, all huddling together, and those in the middle climbing to the top and treading on the others, and waging fierce battles with each other, and many of them dying from want of food.

And the birds had already begun to settle upon men and other animals, no longer finding any land left unsubmerged which was not covered with living creatures. Already had hunger, the minister of death, taken away their life from the greater number of the animals, when the dead bodies already becoming lighter began to rise from out the bottom of the deep waters, and emerged to the surface among the contending waves; and there lay beating one against another, and as balls puffed up with wind rebound back from the spot where they strike, these fell back and lay upon the other dead bodies.

And above these horrors the atmosphere was seen covered with murky clouds that were rent by the jagged course of the raging thunderbolts of heaven, which flashed light hither and thither amid the obscurity of the darkness.

The velocity of the air is seen by the movement of the dust stirred by the running of a horse; and it moves as swiftly to fill up the void left in the air which had enclosed the horse as is the speed of the horse in passing away from the aforesaid space of air.

But it will perhaps seem to you that you have cause to censure me for having represented the different courses taken in the air by the movement of the wind, whereas the wind is not of itself visible in the air; to this I reply that it is not the movement of the wind itself but the movement of the things carried by it which alone is visible in the air.

The divisions

Darkness, wind, tempest at sea, deluge of water, woods on fire, rain, thunderbolts from the sky, earthquakes and destruction of mountains, levelling of cities.

Whirlwinds which carry water and branches of trees and men through the air.

Branches torn away by the winds crashing together at the meeting of the winds, with people on the top of them.

Trees broken off laden with people.

Ships broken in pieces dashed upon the rocks.

Hail, thunderbolts, whirlwinds.

Herds of cattle.

People on trees which cannot bear them: trees and rocks, towers, hills crowded with people, boats, tables, troughs and other contrivances for floating,—hills covered with men and women and animals, with lightnings from the clouds which illumine the whole scene.

Windsor: Drawings 12665 v.

DESCRIPTION OF THE DELUGE

First of all let there be represented the summit of a rugged mountain with certain of the valleys that surround its base, and on its sides let the surface of the soil be seen slipping down together with the tiny roots of the small shrubs, and leaving bare a great part of the surrounding rocks. Sweeping down in devastation from these precipices, let it pursue its headlong course, striking and laying bare the twisted and gnarled roots of the great trees and overturning them in ruin. And the mountains becoming bare should reveal the deep fissures made in them by the ancient earthquakes; and let the bases of the mountains be in great part covered over and clad with the débris of the shrubs which have fallen headlong from the sides of the lofty peaks of the said mountains, and let these be mingled together with mud, roots, branches of trees, with various kinds of leaves thrust in among the mud and earth and stones. And let the fragments of some of the mountains have fallen down into the depth of one of the valleys, and there form a barrier to the swollen waters of its river, which having already burst the barrier rushes on with immense waves, the greatest of which are striking and laying in ruin the walls of the cities and farms of the valley. And from the ruins of the lofty buildings of the aforesaid cities let there rise a great quantity of dust, mounting up in the air with the appearance of smoke or of wreathed clouds that battle against the descending rain.

But the swollen waters should be coursing round the pool which confines them, and striking against various obstacles with whirling eddies, leaping up into the air in turbid foam, and then falling back and causing the water where they strike to be dashed up into the air; and the circling waves which recede from the point of contact are impelled by their impetus right across the course of the other circling waves which move in an opposite direction to them, and after striking against these they leap up into the air without becoming detached from their base.

And where the water issues forth from the said pool, the spent waves are seen spreading out towards the outlet; after which, falling or descending through the air, this water acquires weight and impetus; and then piercing the water where it strikes, it tears it apart and dives down in fury to reach its depth, and then recoiling, it springs back again towards the surface of the lake accompanied by the air which has been submerged with it, and this remains in the slimy foam [1] mingled with the driftwood and other things lighter than the water, and around these again are formed the beginnings of the waves, which increase the more in circumference as they acquire more movement; and this movement makes them lower in proportion as they acquire a wider base, and therefore they become almost imperceptible as they die away. But if the waves rebound against various obstacles then they leap back and oppose the approach of the other waves, following the same law of development in their curve as they have already shown in their original movement. The rain as it falls from the clouds is of the same colour as these clouds, that is on its shaded side, unless, however, the rays of the sun

[1] Richter's transcript (§609) is 'vissci cholla', and he reads 'nella *uscita* colla sciuma'. The MS. has, I think, 'visscichosa', which I have taken as a variant of 'vischiosa'.

should penetrate there, for if this were so the rain would appear less dark than the cloud. And if the great masses of the débris of huge mountains or of large buildings strike in their fall the mighty lakes of the waters, then a vast quantity of water will rebound in the air, and its course will be in an opposite direction to that of the substance which struck the water, that is to say the angle of reflection will be equal to the angle of incidence.

Of the objects borne along by the current of the waters, that will be at a greater distance from the two opposite banks which is heavier or of larger bulk. The eddies of the waters revolve most swiftly in those parts which are nearest to their centre. The crests of the waves of the sea fall forward to their base, beating and rubbing themselves against the smooth particles which form their face; and by this friction the water as it falls is ground up in tiny particles,[1] and becomes changed to thick mist, and is mingled in the currents of the winds in the manner of wreathing smoke or winding clouds, and at last rises up in the air and becomes changed into clouds. But the rain which falls through the air, being beaten upon and driven by the current of the winds, becomes rare or dense according to the rarity or density of these winds, and by this means there is produced throughout the air a flood of transparent clouds which is formed by the aforesaid rain, and becomes visible in it by means of the lines made by the fall of the rain which is near to the eye of the spectator.[2] The waves of the sea that beats against the shelving base of the mountains which confine it, rush [3] foaming in speed up to the ridge of these same hills, and in turning back meet the onset of the succeeding wave, and after loud roaring return in a mighty flood to the sea from whence they came. A great number of the inhabitants, men and different animals, may be seen driven by the rising of the deluge up towards the summits of the hills which border on the said waters.

Waves of the sea at Piombino all of foaming water.

[1] MS., *e ttal confreghatione trita in minute partichule la dissciente acqua.*

[2] MS., 'ce p(er) quessto si gienera infrallaria vna innondatione di trassparēti *nuvoli la quale effacta dalla p(r)edetta pioggia e inquassta si fa manifessta mediante i liniameti* fatti dal disscieso della pioggia che e vicina all ochio che la vede'. The words printed in italics are wanting in the text as given by Dr. Richter (§609).

[3] Dr. Richter reads *saranno* (for MS. *sarrano*), but the text is, I think, *scorrano,* presumably for *scorrono.*

Of the water that leaps up—[of the place where the great masses fall and strike the waters] [1]—of the winds of Piombino.

Eddies of winds and of rain with branches and trees mingled with the air.

The emptying the boats of the rain water.

Windsor: Drawings 12665 r.

[1] The sentence within brackets is crossed through in the MS.

XXX
Colour

'Make the perspective of the colours so that it is not at variance with the size of any object, that is, that the colours lose part of their nature in proportion as the bodies at different distances suffer loss of their natural quantity.'

OF COLOURS

Of colours of equal whiteness that will seem most dazzling which is on the darkest background, and black will seem most intense when it is against a background of greater whiteness.

Red also will seem most vivid when against a yellow background, and so in like manner with all the colours when set against those which present the sharpest contrasts. C.A. 184 v. c

The more white a thing is the more it will be tinged with the colour of the illuminated or luminous object. C.A. 262 r. c

But in the far distance that object will show itself most blue which is darkest in colour. C.A. 305 r. a

Every object that has no colour in itself is tinged either entirely or in part by the colour [of the object] set opposite to it. This may be seen by experience, for every object which serves as a mirror is tinged with the colour of the thing that is reflected in it. And if the object which is in part tinged is white, the portion of it that is illumined by red will appear red, and so with every other colour whether it be light or dark.

Every opaque object that is devoid of colour partakes of the colour of that which is opposite to it: as happens with a white wall.

A 19 v.

OF COLOUR AND FRAGRANCE

Note how spirit (*acqua vite*) collects in itself all the colours and scents of the flowers; and if you wish to make azure, put cornflowers and then wild poppies. B 3 v.

[*Of distant colour*]

The variation in the colours of objects at a great distance can only be discerned in those portions which are smitten by the solar rays. C 12 v.

As regards the colours of bodies there is no difference at a great distance in the parts which are in shadow. C 13 r.

A dark object will appear more blue when it has a larger amount of luminous atmosphere interposed between it and the eye, as may be seen in the colour of the sky. C 18 r.

[*A discussion on the colours of shadows*]

PAINTING

Colours seen in shadow will reveal more or less of their natural beauty in proportion as they are in fainter or deeper shadow.

But if the colours happen to be in a luminous space they will show themselves of greater beauty in proportion as the luminosity is more intense.

Adversary

The varieties in the colours of shadows are as numerous as the varieties in colour of the objects which are in the shadows.

Reply

Colours seen in shadow will reveal less variety one with another according as the shadows wherein they lie are deeper. There is evidence of this from those who from a space without peer within the doorways of shadowy temples, for there the pictures clad as they are in divers colours all seem robed in darkness.

So therefore at a long distance all the shadows of different colours appear of the same darkness.

Of bodies clad in light and shade it is the illuminated part which reveals the true colour. E 18 r.

No white or black is transparent. F 23 r.

PAINTING

Since white is not a colour but is capable of becoming the recipient of every colour, when a white object is seen in the open air all its shadows are blue; and this comes about in accordance with the fourth proposition, which says that the surface of every opaque body partakes of the colour of surrounding objects. As therefore this white object is deprived of the light of the sun by the interposition of some object which comes between the sun and it, all that portion of it which is exposed to the sun and the atmosphere continues to partake of the colour of the sun and the atmosphere, and that part which is not exposed to the sun remains in shadow, and partakes only of the colour of the atmosphere.

And if this white object should neither reflect the green of the fields which stretch out to the horizon nor yet face the brightness of the horizon itself, it would undoubtedly appear of such simple colour as the atmosphere showed itself to be. F 75 r.

OF THE ACCIDENTAL COLOURS OF TREES

The accidental colours of the leaves of trees are four, namely shadow, light, lustre and transparency.

OF THE VISIBILITY OF THESE ACCIDENTAL COLOURS

The accidental parts of the leaves of plants will at a great distance become a mixture, in which the accidental colour of the largest will predominate. G 24 r.

OF PAINTING

The colour of the object illuminated partakes of the colour of that which illuminates it. G 37 r.

The surface of every body participates in the colour of the body that illuminates it:

And in the colour of the air that is interposed between the eye and this body, that is to say in the colour of the transparent medium interposed between the object and the eye.

Among colours of the same quality, the second will never be of the same colour as the first; and this proceeds from the multiplication of the colour of the medium interposed between the object and the eye.

G 53 V.

Of the various colours other than blue, that which at a great distance will resemble blue most closely will be that which is nearest to black, and so conversely the colour which least resembles black will be the one which at a great distance will most retain its natural colour.

Accordingly, the green in landscapes will become more changed into blue than will the yellow or the white, and so conversely the yellow and the white will undergo less change than the green, and the red still less. L 75 V.

The shadow of flesh should be of burnt *terra verde*. L 92 R.

The image imprinted in a mirror partakes of the colour of the said mirror. B.M. 211 V.

The surface of every dark body will participate in the colour of the bodies placed against it. Forster III 74 V.

The surface of every opaque body will be capable of participating and will be tinged with the colour of the bodies placed against it.

Forster III 75 R.

PAINTING

[*The apparent colours of smoke on the horizon*]

The density of smoke from the horizon downwards is white and from the horizon upwards it is dark; and, although this smoke is in itself of the same colour, this equality shows itself as different, on account of the difference of the space in which it is found.

Quaderni IV 3 R.

[Colour of flame]

As flame extends it becomes yellow in its upper part, then saffron in colour, and this ends in smoke. Quaderni IV 10 v.

PAINTING

The surface of every opaque body participates in the colour of its object.

The surface of the opaque body is the more completely steeped in the colour of its object, in proportion as the rays of the images of these objects strike the objects at more equal angles.

And the surface of opaque bodies is more steeped in the colour of their object, in proportion as this surface is whiter, and the colour of the object more luminous or illuminated. Quaderni VI 22 r.

WHETHER THE COLOURS OF THE RAINBOW ARE CREATED BY THE SUN

The colours of the rainbow are not created by the sun, because in many ways these colours are produced without the sun, as happens when you hold up a glass of water close to the eye, for in the glass of it there are the tiny bubbles which are usually seen in glass that is imperfectly refined. And these bubbles although they are not in sunlight will produce on one side all the colours of the rainbow; and this you will see if you place the glass between the atmosphere and your eye in such a way as to be in contact with the eye, the glass having one side exposed to the light of the atmosphere, and on the other the shadow of the wall on the right or left side of the window, which side does not matter. So by turning this glass round you will see the aforesaid colours round about these bubbles in the glass. And we will speak of other methods in their place.

HOW THE EYE HAS NO SHARE IN THE CREATION OF THE COLOURS OF THE RAINBOW

The eye in the experiment described above would seem to have some share in the creation of the colours of the rainbow, because the bubbles in the glass do not display these colours except through the medium of the eye. But if you place this glass full of water on the level of the window, so that the sun's rays strike it on the opposite side, you will then see the aforesaid colours producing themselves, in the impression made by the solar rays which have penetrated through this glass of water, and terminated upon the floor in a dark place at the foot of the window; and since here the eye is not employed we clearly can say with certainty that these colours do not derive in any way from the eye.

OF THE COLOURS FOUND IN THE FEATHERS OF CERTAIN BIRDS

There are many birds in the various regions of the world in whose feathers most radiant colours are seen produced in their different movements, as is seen happen among us with the feathers of peacocks, or on the necks of ducks or pigeons.

Moreover on the surface of ancient glass found buried, and in the roots of radishes which have been kept a long time at the bottom of wells or other stagnant water [we see] that each of these roots is surrounded by a sequence of colours like those of the rainbow. It is seen when some oily substance has spread on the top of water; as also in the solar rays reflected from the surface of a diamond or beryl. Also, in the facet of the beryl, every dark object which has as its background the atmosphere or other clear object is surrounded by this sequence of colours interposed between the atmosphere and the dark object; and so in many other ways which I leave because these suffice for this present theme. Windsor: Drawings 19150 r.

XXXI

Landscape

'Describe landscapes with wind and water and at the setting and rising of the sun.'

WITHIN the spaces between the rain one sees the redness of the sun, that is of the clouds interposed between the sun and the rain.

The waves interposed between the rain and the eye never reveal to the eye the image of the darkness of this rain, and this is due to the fact that the side of the wave is not seen nor does it see the rain.

And the clouds are of dark purple. C.A. 38 r. b

Of things seen through the mist the part which is nearest to the extremities will be less visible, and so much less when they are more remote. C.A. 76 r. b

A mountain that stretches above a city which raises dust in the form of clouds, but the colour of this dust is varied by the colour of these clouds; and, where the rain is thickest, the colour of the dust is least visible; and, where the dust is thickest, the rain is least visible; and, where the rain is mingled with the wind and the dust, the clouds created by the rain are more transparent than those of the dust.

And when the flames of the fire are mingled with clouds of smoke and steam this creates dark and very thick clouds.

The rest of this discourse will be treated of clearly in the book of painting.

[*With drawing*]

The trees, smitten by the course of the winds, bend towards the place where the wind is moving, and after the wind has passed they bend in the opposite movement, that is in the reflex movement.

The mighty fury of the wind, driven by the avalanches of the mountains above the yawning caverns, by means of the avalanches of the mountains which formed a covering to these caverns. C.A. 79 r. c

When rain is falling from broken clouds one sees the shadows of these clouds upon the earth interrupted by the part of the earth that is illuminated by the sun.

OF THE RAINBOW

When the sun is lower the arc has a larger circle, and when it is higher it will be the contrary.

When the sun is in the west, hidden behind some small and thick cloud, then this cloud will be surrounded by a ruddy splendour.

C.A. 97 v. a

Why towers and campaniles at a great distance, although of uniform thickness, seem like inverted pyramids.

This arises from the fact that the lower tracts of air being thick and misty veil them more completely, and the more an object is veiled the more the perception of its extremities is lost, and consequently the perception of the object tends to concentrate about its central line.

C.A. 130 v. b

WHERE SHADOW IS LESS THAN LIGHT

In the houses of a city, where one observes that the divisions between them are clear when it is misty below, if the eye is above the level of the houses the lines of vision, as they descend in the space that is between house and house, plunge into mist which is more dense and therefore, being less transparent, seems whiter; and if one house is higher than another the reality is more to be discerned in the thinner air, and therefore they seem more indistinct in proportion as they are less [1] elevated. C.A. 160 r. a

This came about by reason of the clouds interposed between the earth and the sun, wherefore being in the west it grew red and with its ruddy glow lit as with a haze all the things visible to it, but so much more or less in proportion as these things were nearer or more remote. C.A. 165 v. b

At the first hour of the day the atmosphere in the south near to the horizon has a dim haze of rose-flushed clouds; towards the west it grows darker, and towards the east the damp vapour of the horizon

[1] MS. *più*.

shows brighter than the actual horizon itself, and the white of the houses in the east is scarcely to be discerned, while in the south, the farther distant they are, the more they assume a dark rose-flushed hue, and even more so in the west; and with the shadows it is the contrary, for these disappear before the white.

[. . . .] in the east, and the tops of the trees are more visible than their bases, since the atmosphere is thicker lower down, and the structure becomes more indistinct at a height.

And in the south, the trees may scarcely be distinguished by reason of the vapour which darkens in the west and grows clear in the east.

C.A. 176 r. b

OF PAINTING IN THE COUNTRY

If between the eye and the horizon there intervenes the slope of a hill that drops towards the eye, and the eye finds itself at about the middle of the height of the slope then the hill will acquire darkness with every stage of its length. This is proved by the seventh of this which says; that plant will show itself darker which is seen more below; therefore the proposition is confirmed, because the hill shows from the centre downwards all its plants in the parts which are as much illumined by the brightness of the sky, as the part which is in shade is shaded by the darkness of the earth. For which reason it is necessary that these plants should be of moderate darkness, and from this point on towards the bases of the hills the plants are continually becoming brighter through the converse of the seventh proposition, for by this seventh proposition the nearer such plants are to the summit of the hill the more of necessity they become darker. And it follows that this darkness is not proportionate to the distance, from the eighth proposition which says: that thing will show itself darker which finds itself in finer air; and by the tenth: that will show itself darker which borders on the brighter background. C.A. 184 v. c

OF CITIES OR OTHER BUILDINGS SEEN IN THE EVENING OR MORNING IN THE MIST

Buildings seen at a great distance in the evening or morning through mist or heavy atmosphere, have only such portions in light as are illuminated by the sun which is then near the horizon, and the parts of those buildings which are not exposed to the sun remain almost the same dim neutral colour as the mist.

Why the higher things situated at a distance are darker than the lower ones even though the mist is of uniform thickness:

Of the things situated in mist or any other dense atmosphere, whether this arise from vapour or smoke or distance, that will be most visible which is the highest, and of things of equal height that will seem darkest which is against a background of the deepest mist. As happens with the eye *h*, which beholding *a b c*, towers of equal height, sees *c* the summit of the first tower at *r*, situated below in the mist at two degrees of depth, and sees the summit of the centre tower *b* in only one degree of mist; therefore the summit *c* will show itself darker than the summit of the tower *b*. E 3 V.

PAINTING

The landscapes which occur in representations of winter should not show the mountains blue as one sees them in summer, and this is proved by the fourth part of this [chapter], where it is stated that of the mountains seen at a great distance that will seem a deeper blue in colour which is in itself darker; for when the trees are stripped of their leaves they look grey in colour, and when they are with their leaves they are green, and in proportion as the green is darker than the grey, the green will appear a more intense blue than the grey; and by the fifth part of this [chapter], the shadows of trees which are clad with leaves are as much darker than the shadows of those trees which are stripped of leaves as the trees clad with leaves are denser than those without leaves; and thus we have established our proposition.

The definition of the blue colour of the atmosphere supplies the reason why landscapes are a deeper shade of blue in summer than in winter.

The shadows of trees set in landscapes do not seem to occupy the same positions in the trees on the left as in those on the right, and this especially when the sun is on the right or the left. This is proved by the fourth which states:—opaque bodies placed between the light and the eye will show themselves entirely in shadow; and by the fifth:—the eye that is interposed between the opaque body and the light sees the opaque body all illuminated; and by the sixth:—when the eye and the opaque body are interposed between the darkness and the light the body will be seen half in shadow and half in light.

E 19 r.

OF THE ATMOSPHERE INTERPOSED BETWEEN THE EYE AND THE VISIBLE OBJECT

The object will appear more or less distinct at the same distance, in proportion as the atmosphere interposed between the eye and this object is of greater or less clearness.

Since therefore you are aware that the greater or less quantity of atmosphere interposed between the eye and the object causes the outlines of these objects to seem more or less blurred to the eye, you should represent the stages of loss of definition of these bodies in the same proportion to each other as that of their distances from the eye of the beholder. E 79 v.

When the smoke from dry wood comes between the eye of the observer and some dark space it appears blue.

So the atmosphere appears blue because of the darkness which is beyond it; and if you look towards the horizon of the sky you will see that the atmosphere is not blue, and this is due to its density; and so, at every stage as you raise your eye up from this horizon to the sky which is above you, you will find that the atmosphere will seem darker, and this is because a lesser quantity of air interposes between your eye and the darkness.

And if you are on the top of a high mountain the atmosphere will seem darker above you, just in proportion as it becomes rarer between you and the said darkness; and this will be intensified at every successive stage of its height, so that at the last it will remain blue.

That smoke will appear the bluest which proceeds from the driest wood, and is nearest to the place of its origin, and when it is seen against the darkest background with the light of the sun upon it.

F 18 r.

The smoke that penetrates through the air if it is thick, and rises out of great flame which is fed by damp wood, does not mingle with it but makes itself seem denser above than in the centre, and does this the more when the air is chilly; and the faint gleam that penetrates the air is always warm and always becoming fainter, and of the dust which passes through the air the finest rises the highest. F 88 r.

Although leaves with a smooth surface are for the most part of the same colour on the right side as on the reverse, it so happens that the side exposed to the atmosphere partakes of the colour of the atmosphere, and seems to partake of its colour more closely in proportion as the eye is nearer to it and sees it more foreshortened. And the shadows will invariably appear darker on the right side than on the reverse, through the contrast caused by the high lights appearing against the shadow.

The under side of the leaf, although its colour in itself may be the same as that of the right side, appears more beautiful; and this colour is a green verging upon yellow; and this occurs when the leaf is interposed between the eye and the light which illumines it from the opposite side. Its shadows also are in the same positions as those on the opposite side.

Therefore, O painter, when you make trees near at hand, remember that when your eye is somewhat below the level of the tree you will be able to see its leaves some on the right side and some on the reverse; and the right sides will be a deeper blue as they are seen more foreshortened, and the same leaf will sometimes show part of the right side and part of the reverse, and consequently you must make it of two colours. G 3 r. and 2 v.

When there is one belt of green behind another, the high lights on the leaves and their transparent lights show more strongly than those which are against the brightness of the atmosphere.

And if the sun illumines the leaves without these coming between it and the eye, and without the eye facing the sun, then the high lights and the transparent lights of the leaves are extremely powerful.

It is very useful to make some of the lower branches, and these should be dark, and should serve as a background for the illuminated belts of green which are at some little distance from the first.

Of the darker greens seen from below, that part is darkest which is nearest to the eye, that is to say which is farthest from the luminous atmosphere. G 4 r.

Never represent leaves as though transparent in the sun, because they are always indistinct; and this comes about because over the transparency of one leaf there will be imprinted the shadow of another leaf which is above it; and this shadow has definite outlines and a fixed density. And sometimes it is the half or third part of the leaf which is in the shadow, and consequently the structure of such a leaf is indistinct, and the imitation of it is to be avoided.

The upper branches of the spreading boughs of trees keep nearer to the parent bough than do those below.

That leaf is less transparent which takes the light at a more acute angle. G 4 v.

OF THE PLANTS OF THE FIELDS

Of the plants which take their shadows from the trees which grow among them, those which are in front of the shadow have their stalks lighted up against a background of shadow, and the plants which are in shadow have their stalks dark against a light background, that is against a background which is beyond the shadow.

OF THE TREES WHICH ARE BETWEEN THE EYE AND THE LIGHT

Of the trees which are between the eye and the light, the part in front will be bright, and this brightness will be diversified by the ramification of the transparent leaves—as seen from the under side—with the shining leaves seen from the right side, and in the background, below and behind, the verdure will be dark, because it is cast in shadow by the front part of the said tree; and this occurs in trees which are higher than the eye. G 9 v.

OF DARK LEAVES IN FRONT OF TRANSPARENT ONES

When the leaves are interposed between the light and the eye, then that which is nearest to the eye will be the darkest, and that farthest away will be the lightest, if they are not seen against the atmosphere; and this happens with leaves which are beyond the centre of the tree, that is in the direction of the light. G 10 V.

OF TREES AND THEIR LIGHT

The true method of practice in representing country scenes, or I should say landscapes with their trees, is to choose them when the sun in the sky is hidden, so that the fields receive a diffused light and not the direct light of the sun, for this makes the shadows sharply defined and very different from the lights. G 11 V.

OF THE SHADOWS OF VERDURE

The shadows of verdure always approximate to blue, and so it is with every shadow of every other thing, and they tend to this colour more entirely when they are farther distant from the eye, and less in proportion as they are nearer.

The leaves which reflect the blue of the atmosphere always present themselves edgewise to the eye.

OF THE ILLUMINATED PARTS OF VERDURE AND OF MOUNTAINS

The part illuminated will show more of its natural colour at a great distance when it is illuminated by the most powerful light. G 15 r.

OF SHADOWS AND LIGHTS ON CITIES

When the sun is in the east and the eye is looking down upon a city from above, the eye will see the southern part of the city with its roofs half in shadow and half in light, and so also with the northern part; but the eastern part will be all in shadow and the western part all in light.

HOW ONE SHOULD REPRESENT LANDSCAPES

Landscapes ought to be represented so that the trees are half in light and half in shadow; but it is better to make them when the sun is covered by clouds, for then the trees are lighted up by the general light of the sky and the general shadow of the earth; and these are so much darker in their parts, in proportion as these parts are nearer to the middle of the tree and to the earth. G. 19 V

OF TREES IN THE SOUTH

When the sun is in the east, the trees in the south and north are almost as much in light as in shadow, but the total amount in light is greater in proportion as they are more to the west, and the total amount in shadow is greater in proportion as they are more to the east.

OF MEADOWS

When the sun is in the east, the grasses in the meadows and the other small plants are of a most brilliant green, because they are transparent to the sun. This does not happen with the meadows in the west, and in those in the south and north the grasses are of a moderate brilliance in their green. G 20 V.

THE ASPECTS OF LANDSCAPES

When the sun is in the east all the parts of trees which are illuminated by it are of a most brilliant green; and this is due to the fact that the leaves illuminated by the sun within half our hemisphere, namely the eastern half, are transparent, while within the western semicircle the verdure has a sombre hue and the air is damp and heavy, of the colour of dark ashes, so that it is not transparent like that in the east, which is refulgent, and the more so as it is more full of moisture.

The shadows of the trees in the east cover a large part of the tree, and they are darker in proportion as the trees are thicker with leaves. G 21 r.

OF TREES IN THE EAST

When the sun is in the east the trees seen towards the east will have the light surrounding them all around their shadows, except towards the earth, unless the tree has been pruned in the previous year; and the trees in the south and in the north will be half in shadow and half in light, and more or less in shadow or in light according as they are more or less to the east or to the west.

The fact of the eye being high or low causes a variation in the shadows and lights of trees, for when the eye is above, it sees the trees with very little shadow, and when below with a great deal of shadow.

The different shades of green of plants are as varied as are their species. G 21 v.

OF THE SHADOWS OF TREES

When the sun is in the east the trees towards the west will appear to the eye with very little relief and of almost imperceptible gradation, on account of the atmosphere which lies very thick between the eye and these trees, according to the seventh [part] of this [treatise]; and they are deprived of shadow, for although a shadow exists in each part of the ramification, it so happens that the images of shadow and light which come to the eye are confused and blended together, and cannot be discerned through the smallness of their size. And the highest lights are in the centre of the trees and the shadows are toward their extremities, and their separation is marked by the shadows in the spaces between these trees when the forests are dense with trees; and in those which are more scattered the contours are but little seen. G 22 r.

OF TREES IN THE EAST

When the sun is in the east the trees in that quarter are dark towards the centre, and their edges are in light.

OF THE SMOKE OF CITIES

The smoke is seen better and more distinctly in the eastern than in the western quarter when the sun is in the east. This is due to two causes: the first is that the sun shines with its rays through the particles of the smoke, and lightens these up and renders them visible; the second is that the roofs of the houses seen in the east at this hour are in shadow, because their slope prevents them from being lighted by the sun; the same happens with the dust, and both the one and the other are more charged with light in proportion as they are thicker; and they are thickest towards the middle. G 22 V.

OF SMOKE AND DUST

When the sun is in the east the smoke of cities will not be visible in the west, because it is neither seen penetrated by the solar rays nor against a dark background, since the roofs of the houses turn the same side to the eye that they show to the sun, and against this bright background the smoke will be scarcely visible. But dust when seen under the same conditions will appear darker than smoke, because it is thicker in substance than smoke, which is made up of vapour.

G 23 r.

[*Of trees penetrated by the air*]

OF THE OPEN SPACES IN TREES THEMSELVES

The intervening region of the air within the bodies of trees, and the spaces between the trees within the air at a great distance, do not reveal themselves to the eye, for where it requires an effort to discern the whole it would be difficult to distinguish the parts. But it forms a confused mixture, which derives most from that which forms the greatest mass. The open spaces of the tree being made up of particles of illuminated air, and being much less than the tree, one therefore loses sight of them much sooner than one does of the tree; but it does not therefore follow that they are not there. Hence of necessity there comes about a blending of air and of the darkness of the shaded tree, which float together to meet the eye of the beholder.

OF TREES THAT COVER UP THESE OPEN SPACES IN ONE ANOTHER

That part of the tree will show fewer open spaces when it has behind it, between the tree and the air, the greater mass of another tree. So with the tree *a* the open spaces are not covered, nor in *b*, because there are no trees behind. But in *c* there is only open space in the half, that is to say that *c* is covered by the tree *d*, and part of the tree *d* is covered by the tree *e*, and a little beyond this all the open spaces within the circumference of the trees are lost, and only those at the sides remain. G 25 V.

OF TREES

What outlines do trees show at a distance against the atmosphere which serves as their background? The outlines of the structure of trees against the luminous atmosphere, as they are more remote, approach the spherical more closely in their shape, and as they are nearer, so they display a greater divergence from the spherical form.

So the first tree *a*[1] as being near to the eye displays the true form of its ramification, but this is somewhat less visible in *b*, and disappears altogether in *c*, where not only can none of the branches of the tree be seen, but the whole tree can only be recognised with great difficulty.

Every object in shadow—be it of whatever shape you please—will at a great distance appear to be spherical; and this occurs because if an object be rectangular, then at a very short distance its angles become invisible, and a little farther off it loses more than it retains of the lesser sides, and so before losing the whole it loses the parts, since these are less than the whole.

So with a man when so situated, you lose sight of the legs, arms and head, before the trunk, and then the extremities of the length become lost before those of the breadth, and when these have become equal there would be a square[2] if the angles remained, but as they are lost there is a sphere. G 26 V.

In the representation of trees in leaf be careful not to repeat the same colour too often, for a tree which has another tree of the same colour as its background, but vary it by making the foliage lighter or darker, or of a more vivid green. G 27 V.

OF THE LIGHTS ON DARK LEAVES

The lights on such leaves as are darkest in colour will most closely resemble the colour of the atmosphere reflected in them; and this is due

[1] MS. contains a sketch of a row of trees seen in perspective.

[2] I have followed Dr. Richter in interpreting a tiny figure in the text as a square. M. Ravaisson-Mollien reads it as *ci*.

to the fact that the brightness of the illuminated part mingling with the darkness forms of itself a blue colour; and this brightness proceeds from the blue of the atmosphere, which is reflected in the smooth surface of these leaves, thereby adding to the blueness which this light usually produces when it falls upon dark objects.

OF THE LIGHTS ON LEAVES OF YELLOWISH GREEN

But leaves of yellowish green do not when they reflect the atmosphere create a reflection which verges on blue; for every object when seen in a mirror takes in part the colour of this mirror; therefore the blue of the atmosphere reflected in the yellow of the leaf appears green, because blue and yellow mixed together form a most brilliant green, and therefore the lustre on light leaves which are yellowish in colour will be a greenish yellow.

OF TREES WHICH ARE ILLLUMINATED BY THE SUN OR BY THE ATMOSPHERE

The trees, illuminated by the sun and by the atmosphere, which have leaves of a dark colour, will be illuminated on one side by the atmosphere alone, and in consequence of being thus illuminated will share its blueness; and on the opposite side they will be illuminated both by the atmosphere and the sun, and the part which the eye sees illuminated by the sun will be resplendent. G 28 v.

The extremities of the branches of trees if not dragged down by the weight of their fruit turn towards the sky as much as possible.

The upper sides of their leaves are turned towards the sky in order to receive nourishment from the dew that falls by night.

The sun gives spirit and life to plants, and the earth nourishes them with moisture. In this connection I once made the experiment of leaving only one small root on a gourd and keeping this nourished with water; and the gourd brought to perfection all the fruits that it could produce, which were about sixty gourds of the long species; and I set myself diligently to consider the source of its life, and I perceived that it was the dew of the night which steeped it abundantly with its moisture through the joints of its great leaves, and thereby nourished the tree and its offspring, or rather the seeds which were to produce its offspring.

The rule as to the leaves produced on the last of the year's branches is that on twin branches they will grow in a contrary direction, that is, that the leaves in their earliest growth turn themselves round towards the branch, in such a way that the sixth leaf above grows over the sixth leaf below; and the manner of their turning is that if one turns towards its fellow on the right, the other turns to the left.

The leaf serves as a breast to nourish the branch or fruit which grows in the succeeding year. G 32 v.

OF LANDSCAPES

The dark colours of the shadows of mountains at a great distance take a more beautiful and purer blue than those parts which are in light, and from this it follows that when the rock of the mountains is reddish the parts of it which are in light are fawn-coloured, and the more brightly it is illuminated the more closely will it retain its natural colour. I 48 r.

OF SMOKE

Smoke enters into the air in the form of a wave, like that which water makes when its force causes it to burst through other water.
I 106 [58] r.

Reeds in the light are scarcely visible, but between the light and the shade they stand out well.

To represent landscapes, choose when the sun is at the meridian and turn to the west or the east, and then begin your work.

If you turn to the north every object placed on that side will be without shadow, and especially those nearest to the shadow cast by your head, and if you turn to the south every object upon that side will be entirely in shadow.

All the trees which are towards the sun and which have the atmosphere for their background will be dark, and the other trees which have this darkness for their background will be black in the centre and lighter towards the edges. L 87 r.

CLASSIFICATION OF TREES

Low, tall, thin, thick, that is with leaves, dark, light, yellow, red, with branches pointing upwards, with branches that meet the eye, with branches that point downwards, with trunks white, those transparent in the air, those not, those massed together, those spread out.

L 87 v.

The line of equality and that of the horizon are the same.

M 36 v.

Landscapes are of a more beautiful azure when in fine weather the sun is at noon, than at any other hour of the day, because the atmosphere is free from moisture; and viewing them under such conditions you see the trees beautiful towards their extremities and the shadows dark towards the centre; and in the farther distance the atmosphere which is interposed between you and them appears more beautiful when beyond it there is some darker substance, and consequently the azure is most beautiful.

Objects seen from the side on which the sun is shining will not show you their shadows. But if you are lower than the sun you will see what was not seen by the sun, and that will be all in shadow.

The leaves of the trees which are between you and the sun are of five principal shades of colour, namely a green most beautiful, shining and serving as a mirror for the atmosphere which lights up objects that cannot be seen by the sun, and the parts in shadow that only face the earth, and those darkest parts which are surrounded by something other than darkness.

Trees in the open country which are between you and the sun seem much more beautiful than those which have you between the sun and themselves; and this is the case because those which are in the same direction as the sun show their leaves transparent towards their extremities, and the parts that are not transparent, that is at the tips, are shining; it is true that the shadows are dark, because they are not covered by anything.

The trees when you place yourself between them and the sun will only show themselves to you in their clear and natural colour, which is not of itself very conspicuous, and besides this certain reflected lights, which, owing to their not being against a background that offers a strong contrast to their brightness, are but little in evidence; and if you are at a lower altitude than these, such parts of them may be visible as are not exposed to the sun, and these will be dark.

IN THE WIND

But if you are on the side from whence the wind is blowing, you will see the trees looking much lighter than you would see them from the other sides; and this is due to the fact that the wind turns up the reverse sides of the leaves, which are in all cases much paler than their right sides; and especially will they be very light if the wind blows from the quarter where the sun happens to be, and if you have your back turned to it. B.M. 113 V.

All trees seen against the sun are dark towards the centre; this darkness will take the shape of the tree when it stands apart from others.

The shadows cast by trees on which the sun is shining are as dark as that of the centre of the tree.

The shadow cast by trees is never less in mass than the mass of the tree; but it is larger in proportion as the place where it is thrown slopes more towards the centre of the earth.

A shadow will be thickest towards the centre of a tree when it has fewest branches.

Every branch gets the middle of the shadow of every other branch and as a consequence of all the tree.

The shape of every shadow of branch or tree is clothed with a bright part on the side from which the light comes; this brightness will be of the same shape as the shadow and may extend for a mile from the side where the sun is.

If it should happen anywhere that a cloud casts a shadow on some part of the hills, the trees there will undergo less change than in the distances or plains; for the trees upon the hills have their branches thicker because their growth each year is less than in the plains; therefore as they are of the number of those naturally dark and full of shade the shadows of the clouds cannot make them any darker, and the level spaces that come between the trees which have not lost any shadow vary very much in tone, and especially those which are other than green, such as cultivated lands or the havoc of mountains or their barrenness or ruggedness.

Where trees are on the skyline they seem of the same colour, unless they are very close together and with thick-set leaves like the pine and similar trees.

When you see trees on the side on which the sun lights them you will see them of almost uniform brightness, and the shadows which are within them will be covered by the illuminated leaves which come between your eye and the shadows.

When trees come between the sun and the eye beyond the shadows which spread out from their centre you will see the green of the leaves in transparence; but this transparence will be broken in many places by the leaves and branches in shadow which come between you and them, and in the upper portions it will be accompanied by many reflections from the leaves. B.M. 114 r.

When the sun is covered by clouds, objects have a low degree of visibility; because there is but little difference between the lights and shadows of the trees and buildings, through them being illuminated by the spaciousness of the atmosphere, which surrounds the objects in such a way that the shadows are few, and these few become fainter and fainter so that their extremities become lost in mist.

The trees in landscapes are of various different shades of green; for in some, such as firs, pines, cypresses, laurels, box and the like, it borders on black; others such as walnuts and pears, vines and young foliage approximate to yellow; others to darker shades of yellow, such as chestnuts, oaks and the like, others redden towards the autumn, these are sorbs, pomegranates, vines and cherry trees; others such as willows, olives, bamboos, and others like these, tend to become white.

B.M. 114 v.

DESCRIBE LANDSCAPES WITH WIND AND WATER AND AT THE SETTING AND RISING OF THE SUN

All the leaves which hang down towards the ground as the twigs bend, owing to the branches being turned over, straighten themselves in the current of the winds; and here their perspective is inverted, for if the tree is between you and the quarter from which the wind is coming, the tips of the leaves which are towards you take their natural position, and those opposite which should have their tips the contrary way, from the fact of their being upside down, will be turned with their tips towards you.

Trees in a landscape do not stand out distinctly one from another, because their illuminated parts border on the illuminated parts of those beyond them, and so there is little difference between the lights and the shadows.

When clouds come between the sun and the eye all the edges of their rounded masses are clear, and they are dark towards the centre, and this happens because towards the top these edges are seen by the sun from above while you are looking at them from below; and the same happens with the positions of the branches of the trees; and moreover the clouds, like the trees, through being somewhat transparent are partly bright, and at the edges show themselves thinner.

But when the eye finds itself between the cloud and the sun, the appearance of the cloud is the contrary of what it was before, for the edges of its rounded masses are dark and they are bright towards the centre. And this comes about because you are looking at that part which is also facing the sun, and because these edges have a degree of transparency and reveal to the eye the part that is hidden beyond them, and this not being visible to the sun as are the parts which are turned towards it is necessarily somewhat darker. It may also be that you see the details of these rounded masses from the underside while the sun sees it from above, and since they are not so situated as to give back the brightness of the sun as in the former instance, therefore they remain dark.

The black clouds which are often visible above those that are bright and illuminated by the sun, are thrown into shadow by the other clouds which are interposed between them and the sun.

Again the rounded masses of the clouds that face the sun show their edges dark, because they are silhouetted [1] against a bright background; and to see the truth of this you should observe the top of a cloud which

[1] MS. *canpegiano.*

is entirely light because it is silhouetted against the blue of the atmosphere which is darker than the cloud. B.M. 172 v.

OF MOVEMENT

I ask whether the true movement of the clouds can be recognised by the movement of their shadows, and similarly by the movement of the sun. Forster II 46 r.

The sun will appear greater in moving water or when the surface is broken into waves than it does in still water. An example is of the light reflected on the strings of the monochord. Windsor: Drawings 12350

OF CLOUDS SMOKE AND DUST AND FLAMES FROM AN OVEN OR BURNING KILN

The clouds do not display their roundnesses except in those parts which are seen by the sun: other roundnesses are imperceptible because they are in the parts in shadow.

If the sun is in the east and the clouds are in the west, the position of the eye being between the sun and the cloud, it sees the edges of the roundnesses which are the component parts of these clouds as dark, and the portions which are surrounded by these darknesses become light. And this proceeds from the fact that the edges of the rounded forms of these clouds face the sky above and around them, so that it is mirrored in them.

The cloud and the tree display no roundness in those of their parts which are in shadow. Windsor: Drawings 12388

The shadows of clouds are lighter in proportion as they are nearer to the horizon. Windsor: Drawings 12391

That part of a tree which is against a background of shadow is all of one tone, and where the trees or branches are thickest there it is darkest because there is less perforation by the air. But where the branches are on a background of other branches there the luminous parts show themselves brighter and the leaves more resplendent, because of the sun which illumines them.

Windsor: Drawings 12431 v.

PAINTING

The density of smoke below the horizon appears white and above the horizon dark, and even though the smoke is in itself of uniform colour this uniformity will seem to vary, according to the difference of the space in which it is found. Windsor MSS. R 878

XXXII

Light and Shade

'No substance can be comprehended without light and shade; light and shade are caused by light.'

THAT place is most shaded on which the greatest number of shaded rays converge.

That place which is smitten by the shaded rays at the greatest angle is darkest.

That place will be most luminous from which the greatest number of luminous rays are reflected. C.A. 31 v. b

Light is the expeller of darkness. Shadow is the suppression of light.

Primary light is that which is the cause of the lighting of shaded bodies.

And the derived lights are those parts of bodies which are illumined by the primary light.

Primary shadow is that side of a body on which the light does not fall.

Derived shadow is simply the striking of shaded rays.

Each body which creates a concourse of rays fills the surrounding air with an infinite number of its images.

A shaded and luminous concourse is that mass of rays which emanate from a shaded and luminous body running through the air without striking.

Shaded or luminous percussion is that which impedes and cuts above itself the concourse of shaded and luminous rays. C.A. 116 r. b

The shadow in diaphanous and spherical bodies is darker at the top than in the hollow, and darker amid the darkness of the derived shadow of the body of the ball.

Every object seen is surrounded by second objects, and from this it is known: and in proportion as the second object is farther away than the first so much the more does the first cover it from the eye.

C.A. 125 r. b

Among the things of equal obscurity which are situated at a considerable and equal distance, that will appear more obscure which has its station higher up from the earth.

The edges of a derived shadow will be most distinct where it is cast nearest to the original shadow.

A shaded body will appear of less size when it is surrounded by a very luminous background, and a luminous body will show itself greater when it is set against a darker background: as is shown in the heights of buildings at night when there are flashes of lightning behind them. For it instantly appears, as the lightning flashes, that the building loses a part of its height.

And from this it comes to pass that these buildings appear larger when there is mist, or by night, than when the air is clear and illumined. C.A. 126 r. b

The breadth and length of shadow and of light, although through foreshortening it may appear less in quantity, will not therefore appear diminished as to quality either in respect of brightness or darkness.

C.A. 144 v. a

All the illuminated parts of a body which see the whole circle of the luminous body will be the more dissimilar in brightness, one from another, as they are nearer to the source of the light. C.A. 150 r. a

The atmosphere is of itself adapted to gather up instantaneously and to leave behind it every image and likeness of whatever body it sees.

When the sun appears in the eastern horizon it permeates at once the whole of our hemisphere and fills it with its luminous semblance.

All the surfaces of solid bodies turned towards the sun or towards the atmosphere illumined by the sun, become clothed and dyed by the light of the atmosphere or of the sun.

Every solid body is surrounded and clothed with light and darkness.

You will get only a poor perception of the detail of a body when the part visible is all the part in shadow, or only the part that is illumined.

The length of the space which exists between the eye and the solid bodies determines how much the part that is illumined increases, and that in shadow diminishes.

The shape of a body cannot be accurately perceived when its extremities are bounded by something of the same colour as itself, and the eye is between the part in shadow and that in light.

C.A. 179 r. b

No separated shadow can reproduce upon a wall the true form of the body of which it is the shadow, unless the centre of the light is equidistant from the extremities of this body. C.A. 187 v. a

[*Camera Obscura*]

The boundaries of the images of any colour which penetrate through a narrow hole into a dark place will be always of a more powerful colour than its centre. C.A. 190 r. b

Why black painted in juxtaposition with white never seems to show itself more black than where it borders upon black, and white does not show itself more white in juxtaposition with black than with white; as is seen with the images passed through a hole or at the edge of any dark obstacle.

This comes about because the images tinge with their colour the spot on which they fall, and when the different images approach the same spot they make a blend of their colours, and this blend participates more in one colour than in another as the one colour is present in greater quantity than the other.

And the colours are more intense and more sharply defined at their edges than in any other part. C.A. 195 v.

OF THE DARKNESS OF THE SHADOWS OR YOU MAY SAY THE BRIGHTNESS OF THE LIGHTS

Those who have experience use in all intricate things such as trees, meadows, hair, beards and fur, four stages of clearness in order to reproduce the same colour; that is, first a dark foundation, second a blur which has something of the shape of the part, third a clearer and more defined part, fourth the lights more in high parts for movements of the figure [?];[1] it seems however to me that these varieties are

[1] MS., *ilumi più che alte parte moti di figura*

infinite in the case of a continuous quantity, which is in itself divisible to infinity, and thus I prove it:

[*Two diagrams*]

Let *a g* be a continuous quantity and *d* the light that illumines it. I refer now to the fourth which says that that part of the illuminated body will be more luminous which is nearer to the source of its illumination; *g* therefore is darker than *c* in proportion as the line *d g* is longer than the line *d c*. And from the conclusion that such grades of brightness, or if you so prefer of darkness, are not four only, but may be conceived of as infinite, because *c d* is a continuous quantity, and every continuous quantity is divisible to infinity, therefore the variety in the length of the lines that extend from the luminous to the illuminated body is infinite; and the proportion of the lights corresponds to the lengths of the lines between them, which extend from the centre of the luminous body to the part of the object which is illuminated by it.

C.A. 199 V. a

THE ACTION OF LIGHT FROM ITS CENTRE

If the whole light were what caused the shadows behind the bodies placed against it, it would be necessary that that body, which is much less than the light, should have a pyramidal shadow behind itself, and as experience does not confirm this, it must be that it is the centre of the light which performs this function.

HOW NO SPHERICAL BODY CAN CONTINUALLY REVOLVE AS IT MOVES

The cannon-ball from the mortar, if it be of uniform substance, and its surface be equidistant from its centre, and the fire strikes it in the middle, as reason would suggest, must needs take its course without any revolution. Seeing that the fire that expels it is of uniform nature, it drives equally the air which withstands its course, and as this also is equal it offers equal resistance.

Example

Thus for example, one sees the moon, which is also a spherical body and meets with equal resistance, to be much swifter as compared with the cannon-ball, but nevertheless the dark spots that are on it never change their position, and the fact of this change not appearing, clearly confirms the fact that it does not revolve.

A PROOF HOW OBJECTS COME TO THE EYE

If you look at the sun or other luminous object and then shut your eyes, you will see it again in the same form within your eye for a long space of time: this is a sign that the images enter within it.

C.A. 204 r. a

When the intersection of two columns of shadow produces their derived shadows by means of the two luminous ones, it must follow that four derived shadows are produced, and these shadows are composite, and they intersect at four places; and of these intersections there are two that form simple shadow, and two are of composite shadow, and these two simple shadows are produced where the two lights cannot be seen, and the composite shadows are produced where one of the two lights cannot illumine. But the intersections of the composite shadows are produced always by a single luminous body, and of the simple ones by two luminous bodies, and the right intersection of the composite shadow is produced by the left light, and the left intersection is produced by the right light; but the two intersections of the simple shadows, both the upper and the lower, are produced by the two luminous bodies, that is the light on the right and the light on the left.

C.A. 241 r. c

Many minute lustres continue in the far distance and make themselves perceptible.

THE NATURE OF THE LIGHT THAT PENETRATES THE VENT HOLES

With reference to the light that penetrates the vent holes, it may be doubted whether it reconstitutes with the dilatation of its rays as much breadth of impression beyond the vent hole as the width of the body which is the cause of the rays.

And in addition to this, whether this dilatation has a power equal to that of the luminous body. As regards the first doubt the reply is that the dilatation made by the rays after their intersection recreates as much breadth beyond the vent hole as in front of the vent hole, there being as much space from the luminous body to the vent hole as from the vent hole to the impress of its rays; this is proved by the straightness of the luminous rays, from which it follows that there is the same proportion between their breadth and between the distances at which they intersect.

But power does not proceed in the same proportion; as is proved where it is stated: just such proportion exists between the heat and the radiance in the different luminous rays as between their distances from their source. It is proved therefore that the luminous ray loses in heat and radiance in proportion as it is more remote from its luminous body. It is true however that the composite shadows, being derived, and starting from the edges of these vent holes, break this rule by means of their intersections; and this is treated of fully in the second book concerning shadow. C.A. 241 r. d

The rays of the shaded and luminous images intersect after they have penetrated within the vent holes, turning in opposite directions every part of their thickness. C.A. 241 v. c

The shadow will never show itself of uniform density in the place of its incidence, unless this place be equidistant from the luminous body. This is proved by the seventh which says: that shadow will show itself lighter or darker which is against a darker or lighter background; by the eighth of this: that background will have its parts so much darker or lighter as it is more remote from or nearer to the luminous body; and among the positions at an equal distance from the luminous body that will show itself more illuminated which receives the luminous rays at more equal angles. No matter with what inequality of position a shadow is defined, it will always show itself with its true boundaries equal to the shaded body if the eye rests upon the centre of the luminous body.

That shadow will show itself darker that is more remote from its shaded body. C.A. 241 v. d

The image of the sun is all in all the parts of the objects upon which its rays fall, and all in each particular part.

Why in the far distance a radiance which is long will appear round to us, and the horns of the moon do not follow this rule, and yet the light near by follows as its point indicates. C.A. 243 r. a

PROEM

Having, as I think, sufficiently treated of the natures and different characteristics of primary and derived shadows, and the manner of their incidence, it seems to me that the time has now come to explain the different results upon the various surfaces which are touched by these shadows.

SHADOW IS THE WITHHOLDING OF LIGHT

It seems to me that the shadows are of supreme importance in perspective, seeing that without them opaque and solid bodies will be indistinct, both as to what lies within their boundaries and also as to their boundaries themselves, unless these are seen against a background differing in colour from that of the substance; and consequently in the first proposition I treat of shadows, and say in this connection that every opaque body is surrounded and has its surface clothed with shadows and lights, and to this I devote the first book. Moreover these shadows are in themselves of varying degrees of darkness, because they have been abandoned by a varying quantity of luminous rays; and these I call primary shadows, because they are the first shadows and so form a covering to the bodies to which they attach themselves, and to this I shall devote the second book. From these primary shadows there issue certain dark rays, which are diffused throughout the air and vary in intensity according to the varieties of the primary shadows from which they are derived; and consequently I call these shadows derived shadows, because they have their origin in other shadows; and of this I will make the third book. Moreover these derived shadows in striking upon anything create as many different effects as are the different places where they strike; and of this I will make the fourth book. And since where the derived shadow strikes, it is always surrounded by the striking of the luminous rays, it leaps back with these in a reflex stream towards its source and meets the primary shadow, and mingles with and becomes changed into it, altering thereby somewhat of its nature; and to this I will devote the fifth book. In addition to this I will make the sixth book to contain an investigation of the many different varieties of the rebound of the reflected rays, which will modify the primary shadow by as many different colours as there are different points from whence these luminous reflected rays proceed. Further I will make the seventh division treat of the various distances that may exist between the point of striking of each reflected ray and the point from whence it proceeds, and of the various different shades of colour which it acquires in striking against opaque bodies. C.A. 250 r. a

In proportion as the luminous body is nearer to the shaded body, it throws out more light if the luminous body is greater than the dark body.

In proportion as the luminous body is more distant from the shaded body and is less than it, it will give more light.

But in proportion as the luminous body being less than the shaded body is more distant from this shaded body it will give more light.

And if the luminous body being greater than the shaded body is moved farther away from the shaded body, the total amount that is illuminated will continue to diminish until it is approximately half.

C.A. 250 v. a

THE ACTION OF COMPOUND SHADOW

The actions of compound shadows are always made up of contrary movements. That is, that if the concourse of luminous rays before arriving at their point of intersection be touched by an opaque body, all the shadows of that body which break in upon the upper ray will show themselves beyond this point of intersection in the percussion of the lower ray, and as the upper ray becomes the lower after the intersection, so the movements which the shaded body makes within this upper ray will show themselves of contrary movement after this intersection; and this will reveal itself in the incidence of the compound shadow upon the pavement, or on a wall that is struck by the sun or other luminous body.

But if the luminous ray is interrupted by the opaque body some distance from its intersection, the percussion of the derived shadow of the opaque body will make a movement similar to that of the opaque body.

And if these rays are interrupted at the actual point of their intersection, then the shadows of the opaque body will be twofold, and they will move with contrary movements one to another before they reach the point of union.

The derived compound shadow is the cause why the percussion of the solar ray when passing through any kind of angle does not leave its impression on this angle; but portions of . . . so much greater or less . . . in proportion as these impressions are more remote from or nearer to these angles. C.A. 277 v. a

The site that is most luminous will vary according to the different positions of the eye and the light; and the shadow will always be immovable, for whatever the change it makes, the eye sees it.

C.A. 322 v. b

No opaque body can be visible unless it is clothed with a shaded and illuminated surface.

The air and every transparent body becomes a passage from the objects to the eye for the images of those bodies which find themselves either within or beyond them.

Derived light should be surrounded by primitive shadow.

Derived shadow will be surrounded by derived light.

Derived light should be surrounded, in whole or in part, by primitive or derived shadows.

Every opaque body has its image all in all and all in every part of the transparence that surrounds it. C.A. 349 v. d

OF PAINTING

Of the shadows—where they ought to be dark; where the shadows ought to be of a middle degree, and the lights where they ought to be clear.

Where they are darker. Where there ought to be glimmers and reflections, that is lights thrown back in one place, and leaping up again in another.

How lights ought to be so rendered that they draw natural things.

How natural figures when they have intense light on one side seem to be in the deepest shadow on the opposite side.

How men show a small variation from light to shadow when the atmosphere is overcast or the sun is on the point of setting.

For what reason objects as they recede from the eye are perceived poorly and seem to lose clearness of outline, and in the far distance appear blue.

Why things when painted seem greater than they are.

C.A. 360 r. c

That light is brightest which has the greatest angle.

That shadow is darkest which is produced at a most acute angle.

C.A. 385 v. c

Primary and derived shadow are deeper when they are caused by the light of the candle than by that of the atmosphere.

The more the derived shadow which is greater enters in the less, the more the cause of the less is more luminous than the greater.

Tr. 24 a

The edges of the window which are illuminated by two different lights of equal radiance will not throw light of equal quality into the room. Tr. 25 a

[*With sketch*]

At the window *a b* the sun enters into the house; this sun will increase the size of the window and lessen the shadow of a man, with the result that when the said man shall approach this shadow of himself, lost in that which carries the true shape of the window, he will see the contact of the shadows lost and confused by the power of the light, close themselves up and not suffer the solar rays to pass . . .

And the shadow made by the man upon the said contact has precisely the effect that is represented above. A 1 r.

[*With diagram*]

If you wish to measure a height by the shadow of the sun, take a stick which may be one braccio, set it up and wait until the sun makes it cast a shadow of two braccia. Then measure immediately the shadow of the tower, and if this is one hundred braccia the tower will be fifty; and this is a good rule. A 6 r.

That part of a shaded body which is illuminated will transmit to the eye the image of its details more distinctly and more rapidly than that which finds itself in shadow. A 20 r.

LIGHT AND SHADE

Among bodies equal in size and distance that which shines the more brightly seems to the eye nearer and larger. C I r.

The straight edges of bodies will appear broken when they serve as boundary of a dark space streaked by the percussion of luminous rays. C I v.

The body illuminated by the solar rays which have passed through the thick branches of the trees, will cast as many shadows as is the number of the branches interposed between the sun and itself.

The shaded rays which proceed from a pyramidal shaded body will bifurcate when they intersect, and the shadow will be of varying degrees of depth at its points.

A light which is greater than the point and less than the base of the shaded pyramidal body placed in front of it, will cause the shaded body to produce at its percussion a bifurcated shadow of varying degrees of depth.

If a shaded body being smaller than a luminous body casts two shadows, and a shaded body the same size as a luminous body or greater than it casts one, it follows that the pyramidal body of which part is smaller than, part equal to, and part larger than the luminous body, will cast a bifurcated shadow. C 2 r.

The body that receives the solar rays which have passed between the minute ramifications of trees at a great distance will have but a single shadow.

If the body, part in shadow and part in light, be of the shape of a perfect sphere, the base of the luminous pyramid will bear the same proportion to its body as that which the base of the shaded pyramid bears to the shaded body.

In proportion as the percussion made by the convergence of the shadow on the opposite wall is more distant from the luminous body and nearer the source from which it is derived, so much the darker and of more defined contours will it appear. C 2 v.

That luminous body will appear of less radiance which is surrounded by a more luminous background:

I have found that those stars that are nearest the horizon appear larger in form than the others, because they see and are seen by a greater amount of the solar body than when they are above us; and since they see more of the sun they have a greater light. And the body that is most luminous shows itself of greater form, as the sun shows itself in the mist above us, for it seems larger when it is without mist and with the mist it diminishes.

No part of the luminous body is ever visible from the pyramid of pure derived shadow. C 3 r.

[*Movement of shadows*]

If the object is moved slowly before the luminous body and the percussion of the shadow of this object is remote from its object, the movement of the derived shadow will have the same proportion with the movement of the primary, as the space between the object and the light has with that between the object and the percussion of the shadow,—so that when the object moves slowly the shadow is rapid. C 3 v.

That part of the reflection will be brightest in which the reflected rays are shortest.

The darkness caused by a number of shadows intersecting will be in conformity with their cause, which has its beginning and end between smooth surfaces near to each other, of the same quality and directly opposite to each other.

In proportion as the luminous body is greater the course of the luminous and shadow rays will be more mingled together.

This comes about because where the larger number of luminous rays are found, there is most light, and where a lesser number, less light, from which it comes about that the shadow rays enter and mingle with them. C 4 r.

That part of the surface of bodies on which the images of the bodies placed opposite, fall at the largest angle will be tinged most with their colour.

The most luminous part of the illuminated body which encompasses the percussion of the shadow will be that which is nearest to this percussion.

Just as a thing touched by a greater mass of luminous rays becomes brighter, so that will become darker which is struck by a greater mass of shadow rays. C 4 v.

A luminous body will seem more brilliant when it is surrounded by deeper shadow.

The breadth and length of shadow and light, although through foreshortening they become straighter and shorter, will neither diminish nor increase the quality or quantity of their brightness or darkness.

The function of shadow and of light diminished by foreshortening, will be to shade and illumine an object opposite to it, according to the quality and quantity that appear in this object.

The more a derived shadow approaches its penultimate extremities the deeper it will appear. C 5 r.

Perspective

If you cause the rays of the sun to pass through a small hole of the shape of a star you will see beautiful effects of perspective in the percussion caused by the passage of the sun. C 7 r.

SHADOW AND LIGHT

The forms of shadows are three: for if the substance which casts the shadow is equal in size to the light, the shadow is like a column which has no end; if the substance is greater than the light, its shadow is like a pyramid which grows larger as it recedes and of which the length has no end; but if the substance is smaller than the light the shadow resembles a pyramid and comes to an end, as is seen in the eclipses of the moon. C 7 v.

OF LIGHT

The shape of a luminous body although it has length will at a great distance seem round.

This is shown by the flame of the candle, which although it is long seems round at a great distance; and the same thing may happen with the stars, for even if they were horned like the moon they would seem round by reason of their great distance. c 8 r.

Among bodies equal in size and length and equal also in form and depth of shade, that will appear the smaller which is surrounded by a more luminous background.

A shaded body placed between equal lights will cast as many shadows as there are lights, shadows of which one will be darker than the others as the light situated on the opposite side is nearer this body than the others.

A shaded body equidistant between two lights will cast two shadows, one darker than the other in proportion as one of the lights which cause them is greater than the other. c 8 v.

The places occupied by the shadows caused by a small luminous body are, as regards size, similar and corresponding to those of which the visual rays are cut off.

And when the luminous ray has passed through a small hole and been broken upon some opposing object near at hand, the impress of its percussion resembles more the hole through which it has passed than the luminous body from which it proceeds. c 9 r.

The greater the radiance of the luminous body the deeper will be the shadows cast by the bodies it illuminates.

All the shaded bodies that are larger than the pupil, which interpose between the eye and the luminous body, will show themselves dark.

If the eye be placed between the luminous body and the bodies illuminated by this light, it will see these bodies without any shadow. c 10 r.

When a luminous ray has passed through a hole of some unusual shape after a long course, the impression it makes where it strikes resembles the luminous body from which it springs.

It is impossible for the ray born of a luminous spherical body to be able, after a long course, to convey to where it strikes the image of any description of angle that exists in the angular hole through which it passes. C 10 v.

The shape of the derived shadow will always conform to the shape of the original shadow.

A light in the form of a cross thrown on to a shaded body of spherical roundness will produce its shadow in the figure of a cross. C 11 r.

That boundary of the derived shadow is darker which is surrounded by a brighter derived light. C 11 v.

Of things equal in respect of size, brightness, background and length, that which has the smoothest surface will seem largest.

Iron of uniform thickness half of which is heated serves as a proof, for the part that is heated appears larger than the remainder. C 12 r.

[*Of broken shadow*]

The derived shadow which has as its origin and cause a spherical shaded and luminous body, and is broken by the percussion made by it upon different bodies situated at varying degrees of distance, will appear round to the eye that is in front of it situated near to the centre of the original shadow.

A shaded body of spherical rotundity will cast a circular shadow blended [of light and shade] when it has a shaded body of its own substance interposed between it and the sun. C 12 v.

Among shadows of equal quality that nearest the eye will appear least dark.

That shadow will be darker which is derived from a greater number of different shaded and luminous bodies.

It is impossible that simple derived shadows, which spring from different bodies and are caused by a single light, can ever join or touch each other. C 13 v.

[*When adjacent bodies will appear separated*]

If many shaded bodies, so near to each other as to be almost touching, are seen against a luminous background at a great distance, they will seem separated by a great space. C 14 r.

[*When separated bodies will appear adjacent*]

If many luminous bodies are seen in a distant landscape, although they may be separated one from another, they will appear united and joined together.

That part of the air will participate most in its natural darkness which is smitten by the sharpest luminous angle. It is clearly to be understood that where there is a smaller luminous angle there is less light, because the pyramid of this angle has a smaller base, and therefore from this smaller base a lesser number of luminous rays converge at its point.

[*Definitions*]

Darkness is the absence of light.

Shadow is the diminution of light.

Primitive shadow is that which is attached to shaded bodies.

Derived shadow is that which separates itself from shaded bodies and travels through the air.

Repercussed shadow is that which is surrounded by an illuminated surface.

The simple shadow is that which does not see any part of the light which causes it.

The simple shadow commences in the line which parts it from the boundaries of the luminous bodies. C 14 v.

Rays doubled by intersection in lights and shadows are also of double clearness or obscurity:

Primitive light and derived reflected light, when they surround thick and spherical bodies, become the cause of the boundaries of the primitive shadows of these bodies, being so much more distinct and defined in the part near to the lights as the derived light is clearer than the primitive.

That is said to be primitive light which first lights up shaded bodies, and that is called derived which leaps back from these bodies in those parts which are remote from this primitive light.

That part of the primitive shadow will be more luminous which can see more equally the centres of the derived lights.

One may clearly know that that part of the shaded bodies which is seen by a greater quantity is the more luminous, and especially if it is illumined by two lights; as is seen with reflected lights which put in their midst the derived shadow made between them by the dense bodies opposite.

Every luminous body illumines with its whole and with its part the part and the whole of the object turned to face it.

This proposition is very evident, for one cannot deny that where the whole pupil of the eye is looking, there every part of it is looking, and the place seen by this pupil acts in the same way towards it.

C 16 v.

The middle of the length of each derived shadow is in a straight line with the middle of the primitive shadow and of the derived light, and the centres of the shaded and luminous bodies.

This necessarily happens, since as the luminous lines are straight, those which pass by the extremities of the shaded bodies enclose within their concourse all that air which through the intervention of this shaded body cannot see the luminous body, and for this reason it becomes dark. As the body is equally enclosed the parts of the shadow become equal in respect to its centre, because all the parts of shaded bodies are also equidistant from their centre, and so every body has a centre in itself.

As the above-named luminous lines are in contact with each extremity of the thing enclosed within them, they are equidistant from the middle of the length of any object that they enclose.

That part of the primitive and derived shadow will be so much less dark as it is more distant from its centre.

This comes about because the more the shadow separates from its centre the more it is seen by a greater quantity of luminous rays, and every man knows that where there is more light there is less shadow.

C 17 r.

OF THE SUN'S REFLECTION UPON THE WATER

If the sun is seen by all the seas which have the day, all these seas are seen by the sun. Therefore all the illumined water makes itself the mirror of the sun; and by its image all in the whole of this water and all in a part it appears to the eye. I ask therefore why when a ship is travelling and the sun sees itself, the eye does not see the sea all illumined, and why it does not always seem that the sun is travelling along the pathway of the boat.

Definition

The sun makes as many pyramids as there are holes and crevices by which it can penetrate with its rays, and as many as the eyes of the animated beings that look upon it. Therefore as the sun finds itself always the base of each pyramid, the sun mirrored in the water seems to the eye to be as much beneath the water as it is outside it, and this sun thus reflected forms the base of the pyramid which ends in the eye. And this reflected sun will appear as great as the section of the pyramid cut by the surface of the water at *a n* [*figure*]. c 17 v.

Although the shaded and luminous body be of spherical rotundity and equal size, nevertheless its derived shadow will not resemble the rotundity of the body from which it proceeds, but will be of elongated shape if it falls within unequal angles. c 18 r.

[*Of the shapes of shadows*]

The shapes of shadows often resemble the shaded body which is their origin, and often the luminous body which is their cause.

If the shape and size of the luminous body are like that of the shaded body, the primitive and derived shadows will have the shape and size of these bodies, falling within equal angles.

The derived shadow at a certain distance will never resemble the shape of the shaded body from which it proceeds, unless the shape of the light from this illuminating body resembles the shape of the body illuminated by the said light.

Light that is long in shape will cause the derived shadow born from a round body to be wide and low, although it makes its percussion between equal angles.

It is impossible that the shape of the derived shadow should resemble that of the shaded body from which it was born, unless the light that causes it is similar in shape and size to this shaded body. c 18 v.

There will be as much difference in the darkness of two partially shaded rays as between the shadow that results from their blending and its first condition.

It is impossible that from the blending of two complete shadows there should ensue a shadow darker in degree.

It is possible that from the blending of two incomplete shadows may result a perfect shadow *darker in degree than any of the former.*[1]

c 19 r.

Universally all the points that form the extreme points of the pyramidal images of things are continually all in all the air, united and joined together without any intermission.

Necessity causes that nature ordains or has ordained that in all points of the air all the images of the things opposite to them converge, by the pyramidal concourse of the rays that have emanated from these things; and if it were not so the eye would not discern in every point of the air that is between it and the thing seen, the shape and quality of the thing facing it.

That pyramid which proceeds from its base with more unequal angles will be narrower, and will give a less accurate impression of the true width of the base.

Among the many pyramids that are founded upon a single base that will be more powerful which is larger, and that will be larger which has the angles of its base more equal one to the other. c 20 r.

The less the brightness of the derived as compared with that of the original light, the less will its pyramids illumine the spot on which they strike.

The pyramids will illumine the spot on which they strike the less as their angles are finer. c 20 v.

The farther the derived shadow extends from the primitive the brighter it becomes.

Such proportion as the diameter of the derived shadow has to that of the primitive, you will find between the darkness of the primitive shadow and that of the derived.

If the size of the illuminating body should surpass that of the body which is illumined, it will form an intersection of shadow, beyond which the divided shadows will pass off in two different directions, as though they derived from two different lights.

[1] Words crossed out in MS.

That part of the derived shadow will be darker which is nearer to its source.

The above proposition holds good because, where the larger luminous angle is united to the narrower shaded angle, this luminous angle subdues it and almost changes it to its luminous nature. And so it is presumed that, where the larger shaded angle is united with the narrower luminous angle, the shaded will almost transform to its own nature the luminous that is joined to it. C 21 r.

Of things which are the same in size and colour that which is farther away will seem lighter and less in bulk.

The percussion of the derived shadow is always surrounded by shadow that melts into the luminous background.

That part of the shaded body which is struck by the largest luminous angle will be more illuminated than any other. C 21 v.

When there are several bodies of equal size which are equally distant from the eye, that will appear the smaller which is against a more luminous background.

Every visible body is surrounded by light and shade.

Every perfectly round body when surrounded by light and shade will seem to have one of its sides greater than the other, in proportion as the one is more lighted than the other. C 24 r.

If the visual line that sees the shadow made by the light of the candle has an angle equal to that of the shadow, the shadow will almost seem to function beneath the body that causes it, as does the image of the bodies reflected by the water, for they are as much visible beneath it as above. Even so this shadow will so function that its extremity will appear to be as far below the surface on which it is produced, as the summit of the body which causes it is above this surface, as is seen on a wall. C 25 r.

PERSPECTIVE

The eye that finds itself between the light and shade which surround opaque bodies, will see there the shadow separated from the luminous part pass transversely through the centre of this body.

When two objects are seen within the above-mentioned visual pyramids, in such a way as not to fall short of or protrude beyond these lines, although there be a great intervening space between them, this distance, nevertheless, will never be capable of being seen or recognised by the eye.

The greater the distance between the above-named bodies enclosed within visual pyramidal lines, the more necessary is it that there be a proportionate lack of conformity between them. C 27 r.

OF THE THREE KINDS OF LIGHTS WHICH ILLUMINE OPAQUE BODIES

The first of the lights with which opaque bodies are illumined is called particular, and it is the sun or other light from a window or flame. The second is universal, as is seen in cloudy weather or in mist or the like. The third is the composite, that is when the sun in the evening or the morning is entirely below the horizon. E 3 V.

Among bodies in varying degrees of darkness deprived of the same light, there will be the same proportion between their shadows as there is between their natural degrees of darkness, and you have to understand the same of their lights. E 15 r.

PAINTING

You will note in drawing how among shadows some are indistinguishable in gradation and form; and this is proved by the fifth which says:—spherical surfaces have as many different degrees of light and shadow as there are varieties of brightness and darkness reflected from the objects round them.

That part of an opaque body will be more in shadow or more in light which is nearer to the dark body which shades it, or to the luminous body which gives it light.

The surface of every opaque body partakes of the colour of its object, but the impression is greater or less in proportion as this object is nearer or more remote, and of greater or less power.

Objects seen between light and shadow will appear in greater relief than those which are in the light or in the shadow. E 17 r.

In the position of the eye which sees illuminated such part of plants as behold the light, one plant will never appear illuminated like the other. This is proved as follows:—let *c* be the eye that beholds the two plants *b d* which are illuminated by the sun *a*; I affirm that this eye *c* will not perceive the lights in the same proportion to their shadows in the one tree as in the other; for the tree that is nearer to the sun will show itself more in shadow than that farther away, in proportion as the one tree is nearer than the other to the concourse of the solar rays which come to the eye.

When a tree is seen from below, the eye sees the top of it set within the circle formed by its branches.

Remember, O painter, that the degrees of depth of shade in one particular species of tree vary as much as the sparseness or density of its ramifications. E 18 V.

QUALITY OF SHADOWS

As regards the equal diffusion of light, there will be the same proportion between the degrees of obscurity of the shadows produced, as there is between the degrees of obscurity of the colours to which these shadows are joined.

OF THE MOVEMENT OF SHADOW

The movement of the shadow is always more rapid than the movement of the body which produces it, if the luminous body be stationary. This may be proved:—let *a* be the luminous, *b* the shaded body, *d* the shadow. I say that the shaded body *b* moves to *c* in the same time as the shadow *d* moves to *e*, and there is the same proportion of speed to speed over the same time as there is of length of movement to length of movement. Therefore the proportion of the length of the movement made by the shaded body *b* as far as *c*, to the length of the movement made by the shadow *d* as far as *e*, is such as the abovementioned speeds of movement have to each other.

But if the luminous body be equal in speed to the movement of the shaded body, then the shadow and the shaded body will be of equal movements one to another. And if the luminous be swifter than the shaded body, then the movement of the shadow will be slower than the movement of the shaded body.

But if the luminous is slower than the shaded body then the shadow will be swifter than the shaded body. E 30 V.

OF THE PYRAMIDAL SHADOW

The pyramidal shadow produced by the parallel body will be narrower than the shaded body, in proportion as the simple derived shadow is intersected at a greater distance from its shaded body.

OF SIMPLE DERIVED SHADOWS

The simple derived shadows are of two kinds, that is to say one finite in length and two infinite. The finite is pyramidal, and of those that are infinite one is columnar and the other expanding. And all three have straight sides, but the convergent, that is the pyramidal shadow, proceeds from a shaded body that is less than the luminous body, the columnar proceeds from a shaded body equal to the luminous body, and the expanding from a shaded body greater than the luminous body.

OF COMPOUND DERIVED SHADOWS

Compound derived shadows are of two kinds, that is, columnar and expanding. E 31 r.

OF LIGHT AND LUSTRE

The difference that exists between light and lustre that reveals itself on the smooth surface of opaque bodies:—The lights that are produced on the smooth surfaces of opaque bodies will be stationary in stationary bodies, although the eye which sees them moves; but there will be lustres upon the same bodies in as many points of its surface as are the positions upon which the eye rests.

Which bodies are those that have light without lustre?

Opaque bodies which have a thick rough surface will never produce lustre in any portion of their illuminated part.

Which bodies are those that have lustre and have no illuminated part?

Thick, opaque bodies, with smooth surface, are those which have all the lustre in as many places, in the illuminated part, as there are positions that can receive the angle of the incidence of the light and of the eye, but, because such surface reflects all the things that surround the light, the illuminated body is not distinguishable in this part of the illuminated background.

A luminous body of long shape will make the contours of its derived shadow more indistinct than light that is spherical, and this it is that controverts the following proposition:—that shadow will have its contours more distinct which is nearer the primitive shadow, or if you prefer, the shaded body, but of this the long shape of the luminous body is the cause. E 31 V.

OF SHADOW

Derived shadows are of three kinds, of which one is expanding, another in the form of a column, the third converging at the point of the intersection of its sides which continue beyond in infinite length and straightness. And if you should say that this shadow is terminated in the angle formed by the meeting of its sides and does not pass beyond, this is controverted by the fact that, in the first concerning shadows, it was proved that a thing is entirely ended when no part of it exceeds its terminating lines; and, in the case of this shadow, one sees the contrary, inasmuch as where this derived shadow originates, there there are manifestly created the figures of two shaded pyramids which meet at their angles. If however as the adversary says, the first shaded pyramid terminates the derived shadow with its angle, from whence does the second shaded pyramid proceed? The adversary says that it is caused by the angle and not by the shaded body, but this is denied by the help of the second of this, which says:—the shadow is an accident created by the shaded bodies interposed between the position of this shadow and the luminous body.

Thus it has become clear that the shadow is not produced by the angle of the derived shadow but only by the shaded body.

If a spherical shaded body is illumined by an elongated luminous body, the shadow that is produced by the longest part of this luminous body will have its contours less defined than that produced by the breadth of the same light. And this is proved by what was said before, namely that that shadow is of less defined contours which is created by a greater luminous body, and conversely that shadow is of more defined contours[1] which is lit by a smaller luminous body.

Broken shadows is the term given to those which are seen on a bright wall or other luminous object.

That shadow will seem the darker which is against a lighter ground.

The contours of the derived shadows will be more distinct when they are nearer to the primitive shadow.

The derived shadow will have the contours of its impress more distinct when they cut against the wall within more equal angles.

That part of the same shadow will seem darker which has over against it darker objects; and that will seem less dark which is facing a brighter object. And the bright object when it is larger will shine more brightly.

And that dark object which is of greater bulk will darken the derived shadow most in the place of its percussion. E 32 r.

The surface of every opaque body shares in the colour of surrounding objects.

Shadow is the diminution of light. Darkness is the exclusion of light.

Shadow is divided into two parts, of which the first is called primary shadow and the second derived shadow.

Primary shadow always serves as a basis for derived shadow.

The boundaries of derived shadows are straight lines.

The darkness of the derived shadow diminishes in proportion as it is farther removed from primary shadow.

That shadow will show itself darker which is surrounded by more dazzling brightness, and it will be less evident when it is produced on a darker ground.

Particular light has as a result that it gives better relief to shaded bodies than does universal light; as may be shown by the comparison of the part of a landscape lit by the sun and that shaded by a cloud which is lit merely by the universal light of the air. E 32 v.

The surface of every opaque body partakes of the colour of its object.

[1] MS., *di termini men noti.*

That part of the surface of the opaque bodies partakes most of the colour of its object which is nearest to it. F I V.

That part of a dark object of uniform thickness will show itself thinner which is seen against a more luminous background.

That part of a luminous body of uniform thickness and radiance will seem thicker which is seen against a darker background.

F 22 r.

The ray of the sun after having passed through the bubbles of the surface of the water, sends to the bottom of the water an image of this bubble which bears the form of a cross. I have not yet investigated the cause, but I judge it to be a result of other small bubbles which are clustered together round the larger bubble. F 28 v.

A luminous hole seen from a dark place, though it be of uniform size, will seem to contract considerably when near to any object whatever that is interposed between the eye and this hole.

This statement is proved by the seventh of this, which shows that the contours of any object interposed between the eye and the light will never be seen distinctly, but confused through the air becoming darker near these contours, this darkness becoming more intense the nearer it is to these contours. F 31 r.

Two separated lights will at a certain distance appear joined and united:

In this case it has been held by many who have made a study of perspective, that the air that surrounds these lights at a great distance is so illuminated that it seems of the nature of these lights, and therefore the light and air that surround them appear to be the same body.

What they say is not true, for if it were the case that the air that surrounds these lights at a great distance was so illuminated as to appear all uniformly luminous, this would be more readily discerned near at hand where the exact shape of the light is known than it would be at a distance, and if, in becoming separated, the perception of the exact shape of this light is lost because it suffers a slight decrease in its radiance, how much more would be the diminution and loss of that radiance of the air, which is much less effulgent than the light!

We shall prove therefore that this increase is caused by two images in the eye.

The excessive brilliance of the light when near to the eye diminishes the visual faculty, seeing that the pupil being hurt contracts and so makes itself less, and as the light becomes more separated the injury to the eye ceases to exist, because the light has less brilliance, and so the pupil increases and sees a greater light. F 35 v.

If there are two luminous bodies somewhat near to each other at a great distance they will seem united:

This can happen for two reasons, of which the first is that in being near to these lights one knows instantly the distance or space that separates them, and the images of them that imprint themselves in our eye are still very distinct, and on the other hand their rays do not touch, whilst at a long distance these images look so near that not only their rays but the luminous bodies seem to touch.

Further, at this distance the pupil which at first was contracted becomes enlarged, because the brilliance of the light is not as powerful as when it was near the eye, and so the eye increasing the size of its pupil sees a thing appearing enlarged.

If all the images were to meet in an angle they would meet in a mathematical point, and this being indivisible all the different kinds would seem to you united; being united the sense would not be able to discern any difference. F 36 r.

If some luminous body can be seen through a very small hole made in a piece of paper, approach the luminous body as nearly as possible with the eye; even though it still may be seen in its entirety it will seem so much less than before as this hole is of less size. F 36 v.

If the shape of the waves were in the figure of a half-circle, as are the bubbles of the water, the converging lines of the images of the sun, which emanate from these waves and come to the eye, would be of a very great angle, if this eye were upon the edge of the sea that comes between it and the sun. F 62 v.

Why does every luminous object that is of long shape appear round in the far distance?

It is never a perfect round, but it happens with it as with the leaden die when beaten and much crushed that it appears round in shape. So this light at a great distance acquires such breadth in every direction, for as that which had been added is equal, and the first stock of light goes for nothing in comparison to what is added, the acquisition makes it appear uniformly round.

And this serves to prove that the horns of every star are imperceptible at a great distance. F 64 r.

OF LIGHTS

The lights which illumine opaque bodies are of four kinds, that is to say, universal, as that of the atmosphere within our horizon, and particular, like that of the sun or of a window or door or other space; and the third is reflected light; and there is also a fourth which passes through substances of the degree of transparency of linen or paper or suchlike things, but not those transparent like glass or crystal or other diaphanous bodies, with which the effect is the same as if there was nothing interposed between the body in shadow and the light that illumines it; and of these we shall treat separately in our discourse.

[*Transparency of leaves*]

The shadows in transparent leaves seen from the underside are the same shadows as those on the right side of this leaf, and the shadow is seen in transparency on the reverse at the same time as the luminous part; but the lustre can never show itself in transparency. G 3 v.

Of trees seen from below and against the light, one behind the other at a short distance, the topmost part of the first will be transparent and clear in great part, and it will stand out against the dark part of the second tree; and so it will be with all in succession which are situated under the same conditions. G 6 r.

The shadows of plants are never black, for where the atmosphere penetrates there cannot be utter darkness. G 8 r.

[*Foliage in light*]

If the light comes from *m* and the eye is at *n*, this eye will see the colour of the leaves *a b* all affected by the colour of *m*, that is of the atmosphere, and that of *b c* will be seen on the underside in transparency, with a very beautiful green colour that verges on yellow.

If *m* is the luminous body which lights up the leaf *s*, all the eyes that see the underside of the leaf will see it of a very beautiful light green because it is transparent.

There will be many occasions when the positions of the leaves will be without shadows, and they will have the underside transparent and the right side shining. G 8 V.

The willow and other similar trees which are pollarded every third or fourth year put out very straight branches. Their shadow is towards the centre where these branches grow, and near their extremities they cast but little shade because of their small leaves and few and slender branches.

Therefore the branches which rise towards the sky will have but little shadow and little relief, and the branches which point downwards towards the horizon spring from the dark part of the shadow. And they become clearer by degrees down to their extremities, and show themselves in strong relief being in varying stages of brightness against a background of shadow.

That plant will have least shadow which has fewest branches and fewest leaves. G 9 R.

The leaf of concave surface seen on the underside from below upward, will sometimes show itself half in shadow and half transparent. Thus let *o p* be the leaf, *m* the light and *n* the eye which will see *o* in shadow, because the light does not strike there between equal angles either on the right side or on the reverse; *p* is lit up on the right side, and its light is seen in transparency on its reverse. G 10 V.

OF SHADOWS ON BODIES

When you represent the dark shadows in shaded bodies, represent always the cause of the darkness, and you should do the same for reflections; this is because the dark shadows proceed from dark objects and the reflections from objects of but little brightness, that is from diminished lights. And there is the same proportion between the illuminated part of bodies and the part lit by reflection as there is between the cause of the light on the bodies and the cause of the reflection.

G 11 V.

OF THE UNIVERSAL LIGHT AS LIGHTING UP TREES

That part of the tree will be seen to be clothed in shadows of least obscurity which is farthest away from the earth.

This may be proved:—let *a p* be the tree, *n b c* the illuminated hemisphere. The under part of the tree faces the earth *p c*, that is on the side *o*, and it faces a small part of the hemisphere at *c d*. But the highest part of the convexity *a* is visible to the greatest mass of the hemisphere, that is *b c*; and for this reason, and because it does not face the darkness of the earth, it remains more illuminated. But if the tree is one thick with leaves, as the laurel, the arbutus, the box or the ilex, then it is different, for though *a* does not see the earth it sees the darkness of the leaves divided by many shadows, and this darkness is reflected upwards on to the undersides of the leaves above; and these trees have the shadows so much darker as they are nearer to the centre of the tree.

G 12 r.

OF LIGHTS BETWEEN SHADOWS

When drawing any object, remember in comparing the potency of the lights of its illuminated portions, that the eye is often deceived into thinking one brighter than it really is. The reason springs from our comparing them with the parts which border on them, for if there are two parts of unequal degrees of brightness, and the less bright borders on a dark part while the brighter is set against a light background, such as the sky or some similar bright surface, then that which is less bright, or I should say less radiant, will appear more radiant and what was more radiant will seem darker. G 12 v.

OF THE LIGHTS OF SHADED BODIES

The painter deceives himself many times in representing the principal lights. G 13 r.

Of representing an arrangement of bodies which receives the particular light of the sun or of another luminous body for its illumination. G 15 r.

SHADOWS AND LIGHTS OF CITIES

When the sun is in the east and the eye is above the centre of a city, the eye will see the southern part of this city with its roofs half in shadow and half in light, and the same towards the north; but those in the east will be entirely in shadow and those in the west entirely in light. G 19 v.

OF PAINTING

The outlines and forms of each part of bodies in shadow are poorly distinguished in their shadows and lights, but in such parts as are between the lights and shadows parts of these bodies are of the first degree of distinctness. G 32 r.

OF SITUATION

Take careful note of the situation of your figures, for you will have the light and shade different if the object is in a dark place with a particular light, and if it is in a bright place with the direct light of the sun, and different also if it is in a dark place with the diffused light of evening or in dull weather, and if it is in the diffused light of the atmosphere lit by the sun. G 33 v.

That part of the primary shadow will be least dark which is at the farthest distance from its extremities.

The derived shadow which borders on the primary shadow will be darker than this primary shadow. H 66 [18] r.

That place will be most luminous which is farthest away from mountains. H 68 [20] r.

The derived shadow is never like the body from which it proceeds, unless the light is of the shape and size of the body in shadow.

The derived shadow cannot be like the primitive in shape unless it strikes within equal angles. H 76 [28] v.

OF THE LUMINOUS RAYS AND THE POWER OF THEIR EXTREMITIES

[*Diagram*]

Because the luminous ray is of pyramidal power, and especially when the atmosphere is uniform, it will come about that when two rays emanating from equal lights meet in a straight line, the ray will be everywhere doubled and of uniform power; for where one has the apex of the pyramid the other has its base, as *n m* shows. I 33 r.

The imprint of the shadow of any body of uniform thickness will never resemble the body from whence it proceeds.

Although a shaded body be pyramidal and equally distant in each of its parts from the luminous object, nevertheless that part of the pyramid which is smaller than the light that illumines it will not throw its shadow any distance from its cause. I 37 v.

OF PAINTING

Shadows and lights are observed by the eye under three aspects. One of these is when the eye and the light are both on the same side of the body which is seen; the second is when the eye is in front of the object and the light behind it; and the third is that in which the eye is in front of the object and the light at the side, in such a way that when the line which extends from the object to the eye meets that which extends from the object to the light, they will at their junction [1] form a right angle. K 105 [25] v.

There is another division, namely that of the nature of the reflected object when placed between the eye and the light in different aspects. K 106 [26] r.

PAINTING

[*Derived shadow*]

The derived shadow is stronger in proportion as it is nearer to its source.

[1] MS., *cōgūtiō*, and so Dr. Richter. M. Ravaisson-Mollien has *cognition.*

The same quality of shadow seems stronger in proportion as it is nearer to the eye.

The percussion and section of the derived shadow is darker in proportion as it is shorter. K III [31] V.

[*Luminous rays*]

That part of the body will be illuminated which is struck by the luminous rays at more equal angles. M 77 V.

The image of the sun will show itself brighter in the small waves than in the large ones. This happens because the reflections or images of the sun occur more frequently in the small waves than in the large ones, and the more numerous brightnesses give a greater light than the lesser number.

The waves which intersect after the manner of the scales of a fir-cone reflect the image of the sun with the greatest splendour; and this occurs because there are as many images as there are ridges of the waves seen by the sun, and the shadows which intervene between these waves are small and not very dark; and the radiance of so many reflections is blended together in the image which proceeds from them to the eye, in such a way that these shadows are imperceptible. B.M. 25 R.

There are two different kinds of light; the one is called free, the other restricted. The free is that which freely illuminates bodies; restricted is that which illuminates bodies in the same manner, through some hole or window. B.M. 170 V.

Lights are of two different natures, the one separated and the other united to bodies.

Separated is that which illuminates the body, united is the part of the body illuminated by this light; the one light is called primary, the other derived.

And so also there are shadows of two kinds; the one primary the other derived. Primary is that which is fastened to bodies, derived is that which is separated from bodies, bearing in itself to the surface of walls the resemblance of its cause. B.M. 171 R.

A simple shadow is one which does not see any light.

A compound shadow is one which is illuminated by one or more lights. B.M. 248 V.

A sieve through which penetrates the luminous air, at a great distance will seem without holes and entirely luminous.

Forster III 35 v.

Between walls at an equal distance and quality which are seen behind the extremities of an opaque body set over against them, that part of the wall will appear more illuminated which is seen by a greater amount of the pupil.

Forster III 36 r.

Among things of equal distance and size that which has the greater light will seem of greater body.

Forster III 42 v.

If the illuminated object is the size of the thing that illuminates, and of that where this light is reflected, the quality of the reflex light will have the same proportion to the intermediate light as this second light has to the first, if these bodies are smooth and white.

Forster III 54 r.

The luminous or illuminated object contiguous to the shadow cuts as much as it touches.

There will be as much lacking in the extremities of the shadows of bodies as is touched by the illuminated or luminous field.

Forster III 87 v.

[*Of shadow*]

Shadow is the diminution of light and of darkness, and it is interposed between darkness and light.

Shadow is of infinite obscurity, and this obscurity may be infinitely diminished.

The beginnings and the ends of shadow extend between light and darkness, and they may be infinitely diminished and increased.

Shadow is the expression of bodies and of their shapes.

The shapes of bodies will convey no perception of their quality without shadow.

Shadow partakes always of the colour of its object.

Of the boundaries of shadows: some are like smoke, with boundaries that cannot be perceived, in others they are distinct.

Keep the drawings for the end of the [book on] shadows. They may be seen in the workshop of Gherardo the miniaturist in San Marco at Florence.

No opaque body is without shadow or light, except when there is a mist lying over the ground when it is covered with snow, or it is the same when it snows in the country; this will be without light and it will be surrounded by darkness.

And this occurs in spherical bodies, because in the case of other bodies which have members, the parts of the members which face each other steep each other in the tone of their surface.

The surface of every body is infused into all the illuminated air which serves as its object.

The surface of opaque bodies has its whole image in all the illuminated air which surrounds it from every quarter.

Make the rainbow in the last book 'On Painting'. But first make the book of the colours produced by the mixture of the other colours, so that by means of these colours used by painters you may be able to prove the genesis of the colours of the rainbow.

Describe how no body is in itself defined in the mirror; but the eye on seeing it in this mirror puts boundaries to it; for if you cause your face to be represented in the mirror the part is like the whole, seeing that the part is all in the whole of the mirror and it is complete in every part of the same mirror; and the same happens with every image of every object set in front of this mirror.

The boundaries of the derived shadow are surrounded by the colours of the illuminated objects which are round the luminous body, the cause of this shadow.

Derived shadow does not exist without primary light: this is proved by the First of this, which states that darkness is the entire privation of light, and shadow is the gradual diminution of darkness and of light; and it partakes so much the more or the less of darkness than of light in proportion as the darkness has been broken up by this light.

What is the cause which makes the boundaries of the shadow confused and indistinct.

Whether it is possible to give the contours of the shadows clear-cut and precise boundaries. Quaderni II 6 r.

[*Of luminous bodies*]

PAINTING

Of bodies equal in size and distance that which is most luminous tinges most with its essence the opposite object.

Of bodies of equal luminosity that which is largest in outline tinges most of the surface of its object, the distance of all being equal.

Of bodies which are equal in luminosity and size that which is nearest tinges its object most. Quaderni II 16 r.

The reason why we know that light has in itself a single centre is as follows:—we recognise clearly that a large light often outspans a small object, which nevertheless, although it surrounds it much more than twice with its rays, always has its shadow appearing on the first surface and it is always visible.

Let *c f* be the large light and *n* the object in front of it which produces the shadow on the wall, and *a b* the wall; it clearly appears that it is not the large light that will cast the shadow of *n* upon the wall; but since the light has a centre in itself I prove by experiment the shadow is cast upon the wall as is shown at *m o t r*. [*Diagram*]

Why to two or in front of two eyes do three things when represented appear as two.

Why in surveying a direction with two sights the first appears untrue.

I say the eye projects an infinite number of lines, and these attach themselves to or mingle with those that come towards it which emanate from the things seen, and only the centre line of this perceptive faculty is that which knows and judges bodies and colours; all the others are false and deceitful.

And when you place two things at a distance of a cubit one from the other, the nearer being close to the eye, the surface of this nearer one will remain far more confused than that of the second, the reason being that the nearer is overrun by a greater number of false lines than the second and so is more uncertain.

[*Diagram*]

Light acts like this because in the effects of its lines and especially in the working of its perspective it is very similar to the eye; and its centre ray carries truth in its testing of shadows. When the object placed in front of it is too rapidly subdued by dim rays, it will cast a shadow broad and disproportionately large and ill defined; but when the object that has to produce the shadow cuts the rays of the light and is near the place of percussion, then the shadow becomes distinct; and this especially when the light is at a distance, because the centre ray at a long distance is less interfered with by false rays, seeing that the lines of the eye and the solar and other luminous rays proceeding through the air are obliged to keep a straight course. Otherwise if they were impeded by the atmosphere being denser or more rarefied they would remain bent at some point, but if the air is free from heaviness or humidity they will observe their straight nature, always carrying back to their point of origin the image of the intercepting object, and if it is the eye the intercepting object will be estimated by its colour as well as by its shape and size. But if the surface of the said interposing object shall have within it some small hole that enters into a room dark not on account of its colour but through absence of light, you will see the rays entering through this small hole transmitting there, to the wall beyond, all the traits of their original both as to colour and form, except that everything will be inverted. Windsor: Drawings 19148 v.

The way in which the images of bodies intersect at the edges of the small holes by which they penetrate:

What difference is there between the manner of penetration of the images which pass through narrow apertures and those which pass through wide ones or those which pass at the sides of shaded bodies.

OF THE MOVEMENT OF THE IMAGES OF IMMOVABLE OBJECTS

The images of the immovable objects move by the moving of the edges of that aperture through which the rays of the images penetrate, and this comes about by the ninth [section] which says:—the images of any body are all in all and all in every part of the area that is round about them. It follows that the moving of one of the edges of the aperture by which these images penetrate to a dark place releases the rays of the images that were in contact with it, and they unite with other rays of those images which were remote from it.

OF THE MOVEMENT OF THE RIGHT OR LEFT OR UPPER OR LOWER EDGE

If you move the right side of the opening the impression on the left will move, being that of the object on the right which entered by this opening, and the same will happen with all the other sides of this opening, and this is proved with the help of the second [section] of this [treatise] which says:—all the rays which carry the images of bodies through the air are straight lines. Therefore as the images of the greatest bodies have to pass through the smallest openings, and beyond this opening to re-form in their utmost expansion, it is necessary that this intersection be uninterrupted. Windsor: Drawings 19149 r.

The images of bodies are all diffused through the air which sees them and all in every part of it.

This is proved:—let *a c* and *e* be objects, of which the images penetrate to a dark place by the small holes *n p*, and imprint themselves on the wall *f i* opposite to these holes; as many impressions will be made at as many different places on this wall as is the number of the said small holes.

OF THE RAYS WHICH CARRY THROUGH THE AIR THE IMAGES OF BODIES

All the smallest parts of the images penetrate one another without occupation the one of the other. . . .

. . . the seventh of this where it is said:—every simulacrum sends forth from itself its images by the shortest line, which of necessity is straight. Windsor: Drawings 19150 v.

Demonstration how every part of light converges in a point.

[*Diagram*]

Although the balls *a b c* have their light from one window, nevertheless if you follow the lines of their shadows you will see that they make intersection and point in the angle *n*. Windsor MS. R 137

Shadow is light diminished by means of the intervention of an opaque body. Shadow is the counterpart of the luminous ray cut off by an opaque body.

This is proved because the shaded ray is of the same shape and size as was the luminous ray in which this shadow projects itself.

Windsor: Drawings 19152 v.

Demonstration and argument why of parts in light some portions are in higher light than others.

[*Diagram*]

Since it is proved that every light with fixed boundaries emanates or appears to emanate from a single point, that part illuminated by it will have those portions in highest light upon which the line of radiance falls, between two equal angles, as is shown above in the lines *a g*, also in *a h*, and similarly in *a l*; and that portion of the illuminated part will be less luminous upon which the line of incidence strikes at two more unequal angles, as may be seen in *b c* and *d*; and in this way you will also be able to discern the parts deprived of light, as may be seen at *m* and *k*.

When the angles made by the lines of incidence are more equal the place will have more light, and where they are more unequal it will be darker.

I will treat further of the cause of the reflection.

Windsor MS. R 575

XXXIII

Perspective

'Perspective is a rational demonstration whereby experience confirms how all things transmit their images to the eye by pyramidal lines.'

SANDRO! you do not say why these second things seem lower than the third.[1]

[*Diagram*]

The eye between two parallel lines will never see them at so great a distance that they meet in a point. C.A. 120 r. d

All the cases of perspective are expressed by means of the five mathematical terms, to wit: point, line, angle, surface and body. Of these the point is unique of its kind, and this point has neither height nor breadth, nor length nor depth, wherefore we conclude that it is indivisible and does not occupy space. A line is of three kinds, namely straight, curved and bent, and it has neither breadth, height nor depth, consequently it is indivisible except in its length; its ends are two points.

An angle is the ending of two lines in a point, and they are of three kinds, namely right angles, acute angles and obtuse angles.

Surface is the name given to that which is the boundary of bodies, and it is without depth, and in such depth as it has it is indivisible as is the line or point, being divided only in respect of length or breadth. There are as many different kinds of surfaces as there are bodies that create them.

Body is that which has height, breadth, length and depth, and in all these attributes it is divisible. These bodies are of infinite and varied forms. The visible bodies are of two kinds only, of which the first is

[1] Fragment probably of a discussion with Botticelli concerning the law of diminishing perspective. References to Sandro [Botticelli] are also to be found in C.A. 313 r. b, p. 555, and *Trattato* (Ludwig) 60.

without shape or any distinct or definite extremities, and these though present are imperceptible and consequently their colour is difficult to determine. The second kind of visible bodies is that of which the surface defines and distinguishes the shape.

The first kind, which is without surface, is that of those bodies which are thin or rather liquid, and which readily melt into and mingle with other thin bodies, as mud with water, mist or smoke with air, or the element of air with fire, and other similar things, the extremities of which are mingled with the bodies near to them, whence by this intermingling their boundaries become confused and imperceptible, for which reason they find themselves without surface, because they enter into each other's bodies, and consequently such bodies are said to be without surface.

The second kind is divided into two other kinds, namely transparent and opaque. The transparent is that which shows its whole self along the whole of its side, and nothing is hidden behind it, as is the case with glass, crystal, water and the like. The second division of bodies of which the surface reveals and defines the shape is called opaque.

This it behoves us to treat of at some length, seeing that out of it are derived an infinite number of cases. C.A. 132 r. b

Perspective

The air is full of an infinite number of images of the things which are distributed through it, and all of these are represented in all, all in one, and all in each. Consequently it so happens that if two mirrors be placed so as to be exactly facing each other, the first will be reflected in the second and the second in the first. Now the first being reflected in the second carries to it its own image together with all the images which are represented in it, among these being the image of the second mirror; and so they continue from image to image on to infinity, in such a way that each mirror has an infinite number of mirrors within it, each smaller than the last, and one inside another.

By this example, therefore, it is clearly proved that each thing transmits the image of [itself] to all those places where the thing itself is visible, and so conversely this object is able to receive into itself all the images of the things which are in front of it.

Consequently the eye transmits its own image through the air to all the objects which are in front of it, and receives them into itself, that is on its surface, whence the understanding takes them and considers them, and such as it finds pleasing, these it commits to the memory.

So I hold that the invisible powers of the images in the eyes may project themselves forth to the object as do the images of the object to the eye.

An instance of how the images of all things are spread through the air may be seen in a number of mirrors placed in a circle, and they will then reflect each other for an infinite number of times, for as the image of one reaches another it rebounds back to its source, and then becoming less rebounds yet again to the object, and then returns, and so continues for an infinite number of times.

If at night you place a light between two flat mirrors which are a cubit's space apart, you will see in each of these mirrors an infinite number of lights, one smaller than another, in succession.

If at night you place a light between the walls of a [room], every part of these walls will become tinged by the images of this light, and all those parts which are exposed to the light will likewise be directly lit by it; that is when there is no obstacle between them to interrupt the transmission of the images.

This same example is even more apparent in the transmission of solar rays, which all [pass] through all objects, and consequently into each minutest part of each object, and each ray of itself conveys to its object the image of its source.

That each body alone of itself fills the whole surrounding air with its images, and that this same air is [able] at the same time to receive into itself the images of the countless other bodies which are within it, is clearly shown by these instances; and each body is seen in its entirety throughout the whole of the said atmosphere, and each in each minutest part of the same, and all throughout the whole of it and all in each minutest part; each in all, and all in every part. C.A. 138 r. b

OF PAINTING

The true knowledge of the form of an object becomes gradually lost in proportion as distance decreases its size. C.A. 176 v. b

[*With drawing*]

Body formed from the perspective by Leonardo Vinci, disciple of experience.

This body may be made without the example of any other body but merely with plain lines. C.A. 191 r. a

Among the various studies of natural processes, that of light gives most pleasure to those who contemplate it; and among the noteworthy characteristics of mathematical science, the certainty of its demonstrations is what operates most powerfully to elevate the minds of its investigators.

Perspective therefore is to be preferred to all the formularies and systems of the schoolmen, for in its province the complex beam of light is made to show the stages of its development, wherein is found the glory not only of mathematical but also of physical science, adorned as it is with the flowers of both. And whereas its propositions have been expanded with much circumlocution I will epitomise them with conclusive brevity, introducing however illustrations drawn either from nature or from mathematical science according to the nature of the subject, and sometimes deducing the results from the causes and at other times the causes from the results; adding also to my conclusions some which are not contained in these, but which nevertheless are to be inferred from them; even as the Lord who is the Light of all things shall vouchsafe to reveal to me, who seek to interpret this light—and consequently I will divide the present work into three parts.

Light, when in the course of its incidence it sees things which have been turned against itself, retains their images in part. This conclusion is proved by results, because the vision as it looks upon the light has a measure of fear. Even so after the glance there remain in the eye the images of vivid objects, and they make the place of lesser light appear in shadow until the eye has lost the trace of the impression of the greater light. C.A. 203 r. a

METHODS OF PERSPECTIVE

If you wish to represent a figure in the corner of a dwelling which shall appear to have been made in a level place, get someone to strip naked, and with the light of a candle make their shadow fall as you wish in the said corner, and draw the outline of it with charcoal; but your sight will wish to be in the spot exactly through a hole placed where the light passed, and again the light of the window after its work will wish to come by the said line, so that the walls joined together in the corner will not be any darker on account of the shadow, the one than the other.

THE LIGHT IN THE OPERATION OF THE LAW OF PERSPECTIVE DOES NOT DIFFER FROM THE EYE

That the light has not any difference from the eye as regards losing the thing which is behind the first object is due to this reason: you know that in swiftness of movement and in concourse of straight lines the visual ray and the ray of light resemble each other. As an example: suppose you hold a coin near to the eye, that space which exists between the coin and the boundary of the position, will be more capable of expansion, in proportion as the part of the boundary of the position which is not visible to the eye is the greater, and the nearer the coin is brought to the eye the more the boundary of the position will be filled up.

OF LIGHT

Of the eye. The same process may be seen with light, for as you bring the said coin nearer or remove it farther from this light you will see the shadow on the opposite wall growing larger or failing, and if you wish an example let it be in this form: have many bodies of different things placed in a large room, then take in your hand a long pole with a piece of charcoal at the point and mark with that on the ground and along the walls all the outlines of the things[1] as they appear against the boundaries of the wall.

Of the light. Then at the same distance and height place a light, and you will see the shadows of the said bodies covering as much of the wall as the part that found itself enclosed within the marks made by the charcoal placed at the point of the pole.

[1] Reading *cose*. MS. has *delle pariete*.

Experiment

If you wish to see a similar experiment place a light upon a table, and then retire a certain distance away, and you will see that all the shadows of the objects which are between the wall and the light remain stamped with the shadow of the form of the objects, and all the lines of their length converge in the point where the light is.

Afterwards bring your eye nearer to this light, using the blade of a knife for a screen so that the light may not hurt your eye, and you will see all the bodies opposite without their shadows, and the shadows which were in the partitions of the walls will be covered as regards the eye by the bodies which are set before them. C.A. 204 v. b

Of things of equal size situated at an equal distance from the eye, that will appear the larger which is whiter in colour.

Equal things equally distant from the eye will be judged by the eye to be of equal size.

Equal things through being at different distances from the eye come to appear of unequal size.

Unequal things by reason of their different distances from the eye may appear equal. C.A. 221 v. c

Many things of great bulk lose their visibility in the far distance by reason of their colour, and many small things in the far distance retain their visibility by reason of the said colour.

An object of a colour similar to that of the air retains its visibility at a moderate distance, and an object that is paler than the air retains it in the far distance, and an object which is darker than the air ceases to be visible at a short distance.

But of these three kinds of objects that will be visible at the greatest distance of which the colour presents the strongest contrast to itself.

C.A. 249 r. c

PERSPECTIVE

That dimness (il mezzo confuso) which occurs by reason of distance, or at night, or when mist comes between the eye and the object, causes the boundaries of this object to become almost indistinguishable from the atmosphere. C.A. 316 v. b

An object placed between the eye and an object of dazzling whiteness loses half its size. C.A. 320 v. b

MIRRORS

If you place a candle between two tall mirrors shaped like curved roofing tiles in the manner here shown [*drawing*], you will see everything that offers resistance melted in this candle with the help of these mirrors. C.A. 338 r. a

If you wish to furnish a proof of how things seen by the eye diminish, it is necessary to fix the eye on the centre of the wall, and the curve of the wall will then give you the true clearness of the things seen.

When the cause of the shadow is near the place where it strikes and distant from the light, you will see the shape of the cause of the severed rays clearly upon the wall. C.A. 353 r. b

Among things of equal size, that will show itself less in form which is farther away from the eye. C.A. 353 v. b

PERSPECTIVE

It is asked of you, O painter, why the figures which you draw on a minute scale as a demonstration of perspective do not appear—notwithstanding the demonstration of distance—as large as real ones, which are of the same height as those painted upon the wall.

And why [representations of] things, seen a short distance away, notwithstanding the distance, seem larger than the reality. Tr. 66 a

WALL OF GLASS

Perspective is nothing else than the seeing of an object behind a sheet of glass, smooth and quite transparent, on the surface of which all the things may be marked that are behind this glass; these things approach the point of the eye in pyramids, and these pyramids are cut by the said glass. A I v.

Citation of the things that I ask to have admitted in the proofs of this my perspective:—I ask that it may be permitted me to affirm that

STUDIES FOR HEAD OF LEDA
Royal Library, Windsor

every ray which passes through air of uniform density proceeds in a direct line from its cause to its object or the place at which it strikes.

OF THE DIMINUTION OF OBJECTS AT VARIOUS DISTANCES

A second object as far removed from the first as the first is from the eye will appear half the size of the first, although they are of the same size.

A small object near at hand and a large one at a distance, when seen between equal angles will appear the same size.

I ask how far away the eye can see a non-luminous body, as for instance a mountain. It will see it to advantage if the sun is behind it, and it will seem at a greater or less distance away according to the sun's place in the sky. A 8 V.

Perspective is a rational demonstration whereby experience confirms how all things transmit their images to the eye by pyramidal lines. By pyramidal lines I mean those which start from the extremities of the surface of bodies, and by gradually converging from a distance arrive at the same point; the said point being, as I shall show, in this particular case located in the eye, which is the universal judge of all objects. I call a point that which cannot be divided up into any parts; and as this point which is situated in the eye is indivisible, no body can be seen by the eye which is not greater than this point, and this being the case it is necessary that the lines which extend from the object to the point should be pyramidal. And if anyone should wish to prove that the faculty of sight does not belong to this point, but rather to that black spot which is seen in the centre of the pupil, one might reply to him that a small object never could diminish at any distance, as for example a grain of millet or panic-seed or other similar thing, and that this thing which was greater than the said point could never be entirely seen. A 10 R.

No object can be of so great a size as not to appear less to the eye at a great distance than a smaller object which is nearer.

A wall surface is a perpendicular plane represented in front of the common point at which the concourse of the pyramids converges. And this wall surface performs the same function for the said point as a flat piece of glass upon which you drew the various objects that you saw through it, and the things drawn would be so much less than the originals, as the space that existed between the glass and the eye was less than that between the glass and the object.

The concourse of the pyramids created by the bodies will show upon the wall surface the variety of the size and distance of their causes.

All these planes which have their extremities joined by perpendicular lines forming right angles must necessarily, if of equal size, be less visible the nearer they rise to the level of the eye, and the farther they pass beyond it the more will their real size be seen.

The farther distant from the eye is the spherical body, the more it is seen. A 10 v.

As soon as ever the air is illuminated it is filled with an infinite number of images, caused by the various substances and colours collected together within it, and of these images the eye is the target and the magnet. A 27 r.

PRINCIPLE OF PERSPECTIVE

All things transmit their image to the eye by means of pyramids; the nearer to the eye these are intersected the smaller the image of their cause will appear. A 36 v.

If you should ask how you can demonstrate these points to me from experience, I should tell you, as regards the vanishing point which moves with you, to notice as you go along by lands ploughed in straight furrows, the ends of which start from the path where you are walking, you will see that continually each pair of furrows seem to approach each other and to join at their ends.

As regards the point that comes to the eye, it may be comprehended with greater ease; for if you look in the eye of anyone you will see your own image there; consequently if you suppose two lines to start from your ears and proceed to the ears of the image which you see of yourself in the eye of the other person, you will clearly recognise that these lines contract so much that when they have continued only a little way beyond your image as mirrored in the said eye they will touch one another in a point. A 37 r. and v.

The thing that is nearer to the eye always appears larger than another of the same size which is more remote. A 38 r.

Perspective is of such a nature that it makes what is flat appear in relief, and what is in relief appear flat. A 38 v.

The perspective by means of which a thing is represented will be better understood when it is seen from the view-point at which it was drawn.

If you wish to represent a thing near, which should produce the effect of natural things, it is impossible for your perspective not to appear false, by reason of all the illusory appearances and errors in proportion of which the existence may be assumed in a mediocre work, unless whoever is looking at this perspective finds himself surveying it from the exact distance, elevation, angle of vision or point at which you were situated to make this perspective. Therefore it would be necessary to make a window of the size of your face or in truth a hole through which you would look at the said work. And if you should do this, then without any doubt your work will produce the effect of nature if the light and shade are correctly rendered, and you will hardly be able to convince yourself that these things are painted. Otherwise do not trouble yourself about representing anything, unless you take your view-point at a distance of at least twenty times the maximum width and height of the thing that you represent; and this will satisfy every beholder who places himself in front of the work at any angle whatever.

If you wish to see a proof of this quickly, take a piece of a staff like a small column eight times as high as its width without plinth or capital, then measure off on a flat wall forty equal spaces which are in conformity with the spaces; they will make between them forty columns similar to your small column. Then let there be set up in front of the middle of these spaces, at a distance of four braccia from the wall, a thin band of iron, in the centre of which there is a small round hole of the size of a large pearl; place a light beside this hole so as to touch it, then go and place your column above each mark of the wall and draw the outline of the shadow, then shade it and observe it through the hole in the iron. A 40 v.

In Vitolone there are eight hundred and five conclusions about perspective. B 58 r.

PERSPECTIVE

No visible body can be comprehended and well judged by human eyes, except by the difference of the background where the extremities of this body terminate and are bounded, and so far as its contour lines are concerned no object will seem to be separated from this background. The moon, although far distant from the body of the sun, when by reason of eclipses it finds itself between our eyes and the sun, having the sun for its background will seem to human eyes to be joined and attached to it. C 23 r.

Perspective comes to aid us where judgment fails in things that diminish. C 27 v.

[*Of perspective in nature and in art*]

It is possible to bring about that the eye does not see distant objects as much diminished as they are in natural perspective, where they are diminished by reason of the convexity of the eye, which is obliged to intersect upon its surface the pyramids of every kind of image that approach the eye at a right angle. But the method that I show here in the margin cuts these pyramids at right angles near the surface of the pupil. But whereas the convex pupil of the eye can take in the whole of our hemisphere, this will show only a single star; but where many small stars transmit their images to the surface of the pupil these stars are very small; here only one will be visible but it will be large; and so the moon will be greater in size and its spots more distinct. You should place close to the eye a glass filled with the water mentioned in [chapter] four of book 113 'Concerning Natural Things', water which causes things congealed in balls of crystalline glass to appear as though they were without glass.

Of the eye. Of bodies less than the pupil of the eye that which is nearest to it will be least discerned by this pupil—and from this experience it follows that the power of sight is not reduced to a point.

But the images of objects which meet in the pupil of the eye are spread over this pupil in the same way as they are spread about in the air; and the proof of this is pointed out to us when we look at the starry heavens without fixing our gaze more upon one star than upon another, for then the sky shows itself to us strewn with stars, and they bear to the eye the same proportions as in the sky, and the spaces between them also are the same. E 15 v.

Natural perspective acts in the opposite way, for the greater the distance the smaller does the thing seen appear, and the less the distance the larger it appears. But this invention constrains the beholder to stand with his eye at a small hole, and then with this small hole it will be seen well. But since many eyes come together to see at the same time one and the same work produced by this art, only one of them will have a good view of the function of this perspective and all the others will only see it confusedly. It is well therefore to shun this compound perspective, and to keep to the simple which does not purport to view planes foreshortened but as far as possible in exact form.

And of this simple perspective in which the plane intersects the pyramid that conveys the images to the eye that are at an equal distance from the visual faculty, an example is afforded us by the curve of the pupil of the eye upon which these pyramids intersect at an equal distance from the visual faculty. E 16 r.

OF EQUAL THINGS THE MORE REMOTE APPEARS LESS

The practice of perspective is divided into [two] parts, of which the first treats of all the things seen by the eye at whatsoever distance, and this in itself shows all these things diminished as the eye beholds them, without the man being obliged to stand in one place rather than in another, provided that the wall does not foreshorten it a second time.

But the second practice is a combination of perspective made partly by art and partly by nature, and the work done according to its rules has no part that is not influenced by natural and accidental perspective. Natural perspective I understand has to do with the flat surface on which this perspective is represented; which surface, although it is parallel to it in length and height, is constrained to diminish the distant parts more than its near ones. And this is proved by the first of what has been said above, and its diminution is natural.

Accidental perspective, that is that which is created by art, acts in the contrary way; because it causes bodies equal in themselves to increase on the foreshortened plane, in proportion as the eye is more natural and nearer to the plane, and as the part of this plane where it is represented is more remote from the eye. E 16 v.

THE PERSPECTIVE OF THE DISAPPEARANCE OF THE OUTLINES OF OPAQUE BODIES

If the true outlines of opaque bodies become indistinguishable at any short distance they will be still more invisible at great distances; and since it is by the outlines that the true shape of each opaque body becomes known, whenever because of distance we lack the perception of the whole we shall lack yet more the perception of its parts and outlines. E 80 r.

OF PAINTING AND PERSPECTIVE

There are three divisions of perspective as employed in painting. Of these the first relates to the diminution in the volume of opaque bodies; the second treats of the diminution and disappearance of the outlines of these opaque bodies; the third is their diminution and loss of colour when at a great distance.

OF THE PERSPECTIVE OF THE DIMINUTION OF OPAQUE BODIES

Among opaque bodies of equal magnitude, the diminution apparent in their size will vary according to their distance from the eye which sees them; but it will be in inverse proportion, for at the greater distance the opaque body appears less, and at a less distance this body will appear greater, and on this is founded linear perspective. And show secondly how every object at a great distance loses first that portion of itself which is the thinnest. Thus with a horse, it would lose the legs sooner than the head because the legs are thinner than the head, and it would lose the neck before the trunk for the same reason. It follows therefore that the part of the horse which the eye will be able last to discern will be the trunk, retaining still its oval form, but rather approximating to the shape of a cylinder, and it will lose its thickness sooner than its length from the second conclusion aforsaid. If the eye is immovable the perspective terminates its distance in a point; but if the eye moves in a straight line the perspective ends in a line, because it is proved that the line is produced by the movement of the point, and our sight is fixed upon the point, and consequently it follows that as the sight moves the point moves, and as the point moves the line is produced. E 80 v.

Of objects of equal size placed at equal distances from the eye the more luminous will appear the greater.

Of equal objects equally distant from the eye the more obscure will appear the less. F 36 r.

Of things removed an equal distance from the eye that will appear to be less diminished which was at first more.

Of things removed from the eye at an equal distance from their first position, that is less diminished which at first was more distant from this eye.

And the proportion of the diminution will be the same as that of the distances at which they were from the eye before their movement.

F 60 v.

SIMPLE PERSPECTIVE

Simple perspective is that which is made by art upon a position equally distant from the eye in each of its parts.

Complex perspective is that which is made upon a position in which no two of the parts are equally distant from the eye. G 13 v.

PERSPECTIVE

If two similar and equal things be placed one behind the other at a given distance, the difference in their size will appear greater in proportion as they are nearer to the eye which sees them. And conversely there will appear less difference in size between them as they are farther removed from the eye.

This is proved by means of the proportions that they have between their distances, for if there are two bodies with as great a distance from the eye to the first as from the first to the second this proportion is called double; because if the first is one braccio distant from the eye and the second is at a distance of two braccia, the second space is double the first, and for this reason the first body will show itself double the second. And if you remove the first to a distance of a hundred braccia and the second to a hundred and one braccia, you will find that the first is greater than the second by the extent to which a hundred is less than a hundred and one, and this conversely.

The same thing also is proved by the fourth of this, which says: in the case of equal things there is the same proportion of size to size as that of distance to distance from the eye that sees them. G 29 V.

DISCOURSE ON PAINTING

Perspective as it concerns Painting is divided into three chief parts, of which the first treats of the diminution in the size of bodies at different distances. The second is that which treats of the diminution in the colour of these bodies. The third of the gradual loss of distinctness of the forms and outlines of these bodies at various distances.

Perspective employs in distances two opposite pyramids, one of which has its apex in the eye and its base as far away as the horizon. The other has the base towards the eye and the apex on the horizon. But the first is concerned with the universe, embracing all the mass of the objects that pass before the eye, as though a vast landscape was seen through a small hole, the number of the objects seen through such a hole being so much the greater in proportion as the objects are more remote from the eye; and thus the base is formed on the horizon and the apex in the eye, as I have said above.

The second pyramid has to do with a peculiarity of landscape, in showing itself so much smaller in proportion as it recedes farther from the eye; and this second instance of perspective springs from the first.

[*Perspective of disappearance*]

In every figure placed at a great distance you lose first the knowledge of its most minute parts, and preserve to the last that of the larger parts, losing, however, the perception of all their extremities; and they become oval or spherical in shape, and their boundaries are indistinct. G 53 V.

The eye cannot comprehend a luminous angle when close to itself.
H 71 [23] r.

PERSPECTIVE

The shadows or reflections of things seen in moving water, that is to say with tiny waves, will always be greater than the object outside the water which causes them.

The eye cannot judge where an object high up ought to descend.
H 76 [28] v.

No surface will reveal itself exactly if the eye which see it is not equally distant from its extremities. H 81 [33] r.

OF ORDINARY PERSPECTIVE

An object of uniform thickness and colour seen against a background of various colours will appear not to be of uniform thickness.

And if an object of uniform thickness and of various colours is seen against a background of uniform colour, the object will seem of a varying thickness.

And in proportion as the colours of the background, or of the object seen against the background, have more variety, the more will their thickness seem to vary, although the objects seen against the background may be of equal thickness. I 17 v.

A dark object seen against a light background will seem smaller than it is.

A light object will appear greater in size when it is seen against a background that is darker in colour. I 18 r.

If the eye be in the middle of a course with two horses running to their goal along parallel tracks, it will seem to it that they are running to meet one another.

This that has been stated occurs because the images of the horses which impress themselves upon the eye are moving towards the centre of the surface of the pupil of the eye. K 120 [40] v.

PAINTING

Foreshorten, on the summits and sides of the hills, the outlines of the estates and their divisions; and, as regards the things turned towards you, make them in their true shape. L 21 r.

Among things of equal velocity, that will appear of slower movement which is more remote from the eye.

Therefore that will appear swifter which is nearer to the eye.

B.M. 134 v.

[*Aerial perspective*]

In the morning the mist is thicker up above than in the lower parts because the sun draws it upwards; so with high buildings the summit will be invisible although it is at the same distance as the base. And this is why the sky seems darker up above and towards the horizon, and does not approximate to blue but is all the colour of smoke and dust.

The atmosphere when impregnated with mist is altogether devoid of blueness and merely seems to be the colour of the clouds, which turn white when it is fine weather. And the more you turn to the west the darker you will find it to be, and the brighter and clearer towards the east. And the verdure of the countryside will assume a bluish hue in the half-mist but will turn black when the mist is thicker.

Buildings which face the west only show their illuminated side, the rest the mist hides.

When the sun rises and drives away the mists, and the hills begin to grow distinct on the side from which the mists are departing, they become blue and seem to put forth smoke in the direction of the mists that are flying away, and the buildings reveal their lights and shadows; and where the mist is less dense they show only their lights, and where it is more dense nothing at all. Then it is that the movement of the mist causes it to pass horizontally and so its edges are scarcely perceptible against the blue of the atmosphere, and against the ground it will seem almost like dust rising.

In proportion as the atmosphere is more dense the buildings in a city and the trees in landscapes will seem more infrequent, for only the most prominent and the largest will be visible.

And the mountains will seem few in number, for only those will be seen which are farthest apart from each other, since at such distances the increases in the density creates a brightness so pervading that the darkness of the hills is divided, and quite disappears towards their summits. In the small adjacent hills it cannot find such foothold, and therefore they are less visible and least of all at their bases.

Darkness steeps everything with its hue, and the more an object is divided from darkness the more it shows its true and natural colour.

B.M. 169 r.

Equal things equally distant from the eye will be judged to be of equal size by this eye.

OF PERSPECTIVE

The shaded and the illuminated parts of opaque bodies will be in the same proportion of brightness and darkness as are those of their objects [that is of the body or bodies which project upon them].

Forster II 5 r.

OF PERSPECTIVE

Of things of equal size that which is farther away from the eye will appear of less bulk. Forster II 15 v.

OF PERSPECTIVE

When the eye turns away from a white object which is illuminated by the sun, and goes to a place where there is less light, everything there will seem dark. And this happens, because the eye that rests upon this white illuminated object proceeds to contract its pupil to such an extent that whatever the original surface that was visible they will have lost more than three quarters of it, and thus lacking in size they will also be lacking in power.

Though you might say to me:—a small bird then would see in proportion very little, and because of the smallness of its pupils the white there would appear black. To this I should reply to you that we are here paying attention to the proportion of the mass of that part of the brain which is devoted to the sense of sight, and not to any other thing. Or—to return—this pupil of ours expands and contracts according to the brightness or darkness of its object, and since it needs an interval of time thus to expand and contract, it cannot see all at once when emerging from the light and going to the shade, nor similarly from the shade to what is illuminated; and this circumstance has already deceived me when painting an eye, and from it I have learnt.

Forster II 158 v.

Among equal things the more remote will seem the smaller; and the proportion of the diminutions will be as that of the distances.

Quaderni IV 10 r.

[*Perspective of colours*]

Make the perspective of the colours so that it is not at variance with the size of any object, that is that the colours lose part of their nature in proportion as the bodies at different distances suffer loss of their natural quantity. Quaderni VI 18 r.

XXXIV

Artists' Materials

'Amber is the latex of the cypress tree.'

SINCE walnuts are covered with a certain thin skin which derives its nature from the husk, unless you peel this off when you are making the oil this husk will tinge the oil, and when you use it in your work the husk becomes separated from the oil and comes to the surface of the picture, and this is what causes it to change. C.A. 4 v. b

TO MAKE RED ON GLASS FOR FLESH COLOUR

Take rubies of Rocca Nera or garnets and mix with *lattimo*,[1] also Armenian bole is good in part. Tr. 71 a

Sap of spurge and milk of the fig tree as a dissolvent. H 65 [17] r.

You will make good ochre if you employ the same method that one uses to make white lead. H 94 [46] v.

VARNISH

Take cypress [oil] and distil it, and have a large jug and put the distilled essence in it with so much water as to make it the colour of amber, and cover it over well so that it does not evaporate; and when it has dissolved add in this jug of the said essence so that it shall be as liquid as you desire. And you must know that the amber is the latex of the cypress tree.

And since varnish is the gum of juniper, if you distil the juniper the said varnish can be dissolved in this essence in the manner spoken of above. Forster I 43 r.

Tap a juniper tree and water its roots, and mix the latex that exudes

[1] *Lattimo*, a substance which has the colour of milk, used by glaziers. *Neri Art. Vetr.* (Fanfani).

with oil of walnut and you will have perfect varnish made with varnish, and this same you will make from the cypress, and you will then have varnish of the colour of amber, beautiful and famous for its quality. Make it in May or April. Forster I 44 v.

TO MAKE POINTS FOR COLOURING IN SECCO

Temper with a little wax and it will not flake. And this wax should be dissolved with water, so that after the white lead has been mixed this water having been distilled may pass away in steam and the wax only remain, and you will make good points. But know that it is necessary for you to grind the colours with a warm stone.

Forster II 159 r.

OIL

Seed of mustard pounded with oil of linseed. Forster III 10 v.

Make oil from seed of mustard, and if you wish to make it more easily mix the seed after grinding it with oil of linseed, and put it all under a press. Forster III 40 r.

FOR STAMPING MEDALS

Paste [is made] of emery mixed with spirits of wine, or iron filings with vinegar, or ashes of walnut-leaves, or ashes of straw rubbed very fine.

The diamond is crushed [by being] wrapped up in lead and beaten with a hammer, the lead being several time spread out and folded up again, and it is kept wrapped up in paper so that the powder may not be scattered. Then melt the lead, and the powder rises to the surface of the lead when it has melted, and it is afterwards rubbed between two plates of steel so that it becomes a very fine powder; afterwards wash it with aqua fortis and the black coating of the iron will be dissolved and will leave the powder clean.

Lumps of emery can be broken up by placing them in a cloth folded many times and hitting it on the side with a hammer; and by this means it goes into flakes bit by bit and is then easily crushed; and if you place it on the anvil you will never break it on account of its size.

The grinder of enamels ought to practise in this way upon plates of tempered steel with a steel press, and then place it in aqua fortis which dissolves all the steel that is eaten away and mingled with this enamel and makes it black, with result that the enamel remains purified and clean.

If you grind it upon porphyry this porphyry is consumed and becomes mingled with the enamel and spoils it, and aqua fortis will never free it from the porphyry because it cannot dissolve it.

If you wish to make a beautiful blue, dissolve with tartar the enamel you have made and then take off the salt.

Brass vitrified makes a fine red. Sul Volo Cover [1] v.

XXXV

Commissions

'Works of fame by which I could show to those who are to come that I have been.'

[Memorandum of order of events in the Battle of Anghiari, drawn up apparently for consultation by Leonardo in the composition of his picture on the wall of the Council Chamber of the Palazzo della Signoria at Florence.]

[Lead]ers of the Florentines.

Neri di Gino Capponi.
Bernardetto de' Medici.
Niccolò da Pisa.
Count Francesco.
Micheletto.
Pietro Gian Paolo.
Guelfo Orsino.
Messer Rinaldo degli Albizi.

You should commence with the oration of Niccolò Piccinino to the soldiers and exiled Florentines, among whom was Messer Rinaldo degli Albizi. Then you should show him first mounting his horse in full armour and the whole army following him: forty squadrons of horse and two thousand foot soldiers went with him.

And the Patriarch at an early hour of the morning ascended a hill in order to reconnoitre the country, that is the hills, fields and a valley watered by a river; and he saw Niccolò Piccinino approaching from Borgo San Sepolcro with his men in a great cloud of dust, and having discovered him he turned to the captains of his men and spoke with them.

And having spoken he clasped his hands and prayed to God; and presently he saw a cloud, and from the cloud St. Peter emerged and spoke to the Patriarch. Five hundred cavalry were despatched by the Patriarch to hinder or check the enemy's attack.

In the foremost troop was Francesco, son of Niccolò Piccinino, and he arrived first to attack the bridge which was defended by the Patriarch[?] [1] and the Florentines.

Behind the bridge on the left he sent the infantry to engage our men who beat off the attack. Their leader was Micheletto who [. . .] was the officer of the watch at the court. Here at this bridge there was a great fight: the enemy conquer and the enemy are repulsed.

Then Guido and Astorre his brother, lord of Faenza, with many of their men, reformed and renewed the combat, and hurled themselves upon the Florentines with such vigour that they regained possession of the bridge, and pushed their advance as far as the tents.

Opposite to these came Simonetto with six hundred cavalry to harass the enemy, and he drove them again from the spot and reoccupied the bridge.

And behind him came another company with two thousand cavalry, and so for a long time the battle swayed.

And then the Patriarch to throw disorder into the ranks of the enemy sent forward Niccolò da Pisa and Napoleone Orsino, a beardless youth, and with them a great multitude of men, and then was done another great deed of arms.

And at this time Niccolò Piccinino pushed up another unit of his followers, and this caused yet another advance by our men; and had it not been for the Patriarch throwing himself into the midst and sustaining his commanders by words and deeds the enemy would have driven them in flight.

And the Patriarch made them set up certain pieces of artillery on the hill, by means of which he spread confusion among the infantry of the enemy. And this disorder was so great that Niccolò began to call back his son and all his followers and they started in flight towards the Borgo. And at this spot there occurred a great slaughter of men, and none escaped save those who were the first to fly or those who hid themselves.

The passage of arms continued until the going down of the sun,

[1] MS. has PP.

and the Patriarch busied himself in withdrawing his troops and burying the dead, and afterwards he set up a trophy.

C.A. 74 r. b and 74 v. c

MONUMENT OF MESSER GIOVANNI GIACOMO DA TRIVULZIO[1]

Cost of the work and material for the horse

A courser, life size, with the rider, requires for the cost of the metal	ducats	500
And for the cost of the iron work which goes inside the model, and charcoal, wooden props, pit for the casting, and for binding the mould, including the furnace where it is to be cast	ducats	200
For making the model in clay and afterwards in wax	ducats	432
And for the workmen who polish it after it has been cast	ducats	450
Total	ducats	1582

Cost of the marble for the tomb

Cost of the marble according to the design. The piece of marble which goes under the horse which is 4 braccia long and 2 braccia 2 inches wide and 9 inches thick, 58 hundredweight, at 4 lire 10 soldi per hundredweight	ducats	58
And for 13 braccia 6 inches of cornice, 7 inches wide and 4 inches thick, 24 hundredweight	ducats	24
And for the frieze and architrave which is 4 braccia 6 inches long, 2 braccia wide and 6 inches thick, 20 hundredweight	ducats	20
And for the capitals made of metal of which there are 8, 5 inches square and 2 inches thick: at the price of 15 ducats each they come to	ducats	120
And for 8 columns of 2 braccia 7 inches, 4½ inches thick, 20 hundredweight	ducats	20

[1] For a discussion of the evidence relating to the project for a sepulchral monument of Marshal Trivulzio of which this is an estimate, see the author's *Mind of Leonardo* (Cape, 1928), pp. 336-9.

And for 8 bases, 5½ inches square and 2 inches high 5 hundredweight	ducats 5
And for the stone, where it is upon the tomb, 4 braccia 10 inches long, 2 braccia 4½ inches wide, 36 hundredweight	ducats 36
And for 8 feet of pedestals, which are 8 braccia long, 6½ inches wide, 6½ inches thick, and 20 hundredweight	ducats 20
And for the cornice that is below, which is [. . .] braccia 10 inches long, 2 braccia 5 inches wide and 4 inches thick, 32 hundredweight	ducats 32
And for the stone of which the recumbent figure (il morto) is to be made, which is 3 braccia 8 inches long, 1 braccia 6 inches wide, 9 inches thick, 30 hundredweight	ducats 30
And for the stone that is beneath the recumbent figure, which is 3 braccia 4 inches long, 1 braccia 2 inches wide, 4½ inches thick	ducats 16
And for the slabs of marble interposed between the pedestals, of which there are 8—9 braccia long, 9 inches wide, 3 inches thick—8 hundredweight	ducats 8
Total	ducats 389

Cost of the work upon the marble

Round the base of the horse there are 8 figures at 25 ducats each	ducats 200
And in the same base are 8 festoons with certain other ornaments, and of these there are 4 at the price of 15 ducats each, and 4 at the price of 8 ducats each	ducats 92
And for squaring these stones	ducats 6
Further for the large cornice, which goes below the base of the horse, which is 13 braccia 6 inches at 2 ducats per braccio	ducats 27
And for 12 braccia of frieze at 5 ducats per braccio	ducats 60
And for 12 braccia of architrave at 1½ ducats per braccio	ducats 18
And for 3 rosettes which form the soffit of the monument, at 20 ducats the rosette	ducats 60

And for 8 fluted columns at 8 ducats each	ducats	64
And for 8 bases at one ducat each	ducats	8
And for 8 pedestals, of which there are 4 at 10 ducats each, which go above the corners, and 4 at 6 ducats each	ducats	64
And for squaring and framing the pedestals at 2 ducats each, there being eight	ducats	16
And for 6 tables with figures and trophies at 25 ducats each	ducats	150
And for making the cornices of the stone which is beneath the recumbent figure	ducats	40
For making the recumbent figure, to do it well	ducats	100
For 6 harpies with candlesticks, at 25 ducats each	ducats	150
For squaring the stone on which the recumbent figure rests, and its cornice	ducats	20
Total	ducats	1075

The total of everything added together is ducats 3046.

C.A. 179 v. a

The Labours of Hercules for Pier F. Ginori.
The Garden of the Medici.[1] C.A. 288 v. b

Francesco.
Antonio: lily and book.
Bernardino: with Jesus.
Lodovico: with three lilies on his breast, with crown at his feet.
Bonaventura: with seraphim.

[1] From the juxtaposition of these two notes in the manuscript the first may perhaps be interpreted as a reference to an intended commission, probably for a work in sculpture, to be executed or studied for among the casts in that Garden of the Medici in the piazza di San Marco, where in the time of Il Magnifico an Academy of the Arts existed under the charge of the sculptor Bertoldo. Its existence is referred to by Vasari in his lives of Donatello and Torrigiano. The fact of Leonardo having worked for a time in this garden is borne witness to in the short biography of him written just before the middle of the sixteenth century by a Florentine known as the Anon mo Gaddiano:

'He lived as a youth with Lorenzo de' Medici Il Magnifico who in order to make provision for him set him to work in the garden of the piazza of San Marco in Florence.'

[*Diagram for Altarpiece*]

Giovita		Faustino
San Piero	Our Lady	Paolo
Elisabetta		Santa Chiara
Bernardino		Lodovico
Bonaventura		Antonio da Padua
San Francesco		

Santa Chiara: with the tabernacle.
Elisabetta: with queen's crown.[1] I 107 [59] r.

[*Notes apparently relating to some commission*]

Ambrogio de Predis.
San Marco.
Board for the window.
Gaspari Strame.
The saints of the chapel.
The Genoese at home. L I r.

[*Note with drawing—apparently of mechanism of stage scenery*]

a b, *c d* is a hill which opens thus: *a b* goes to *c d* and *c d* goes to *e f*; and Pluto is revealed in *g*, his residence.

When Pluto's paradise is opened then let there be devils placed there in twelve pots to resemble the mouths of hell.

There, there should be Death, the Furies, Cerberus, many nude Putti in lamentation. There fires made in various colours. . . .

B.M. 231 v.

[1] Following on his identification of the names at the head of the two lists as those of the two patron saints of Brescia, Dr. Emil Möller has put forward reasons for regarding this sketch as intended for an altar-piece for S. Francesco at Brescia, which he believes to have been contemplated by Leonardo in the year 1479. (See *Repertorium für Kunstwissenschaft*, xxxv.)

[*For heraldic devices—with drawings*]

MESSER ANTONIO GRI, VENETIAN, COMPANION OF ANTONIO MARIA

On the left side let there be a wheel, and let the centre of it cover the centre of the horse's hinder thigh-piece, and in this centre should be shewn Prudence dressed in red, representing Charity, sitting in a fiery chariot, with a sprig of laurel in her hand to indicate the hope that springs from good service.

On the opposite side let there be placed in like manner Fortitude with her necklace in hand, clothed in white which signifies . . . and all crowned, and Prudence with three eyes.

The housing of the horse should be woven of plain gold, bedecked with many peacocks' eyes, and this applies to all the housings of the horse and the coat of the man.

The crest of the man's helmet and his hauberk of peacocks' feathers, on a gold ground.

Above the helmet let there be a half-globe to represent our hemisphere in the form of a world, and upon it a peacock with tail spread out to pass beyond the group, richly decorated, and every ornament which belongs to the horse should be of peacocks' feathers on a gold ground, to signify the beauty that results from the grace bestowed on him who serves well.

In the shield a large mirror to signify that he who really wishes for favour should be mirrored in his virtues. B.M. 250 r.

CHRIST

Count Giovanni, of the household of the cardinal of Mortaro.

Giovannina, face of fantasy; lives at Santa Caterina at the hospital.

Forster II 3 r.

Alessandro Carissimo of Parma for the hand of Christ.

Forster II 6 r.

One who was drinking and left the cup in its place and turned his head towards the speaker.

Another twists the fingers of his hands together and turns with stern brows to his companion.

Another with hands opened showing their palms raises his shoulders towards his ears and gapes in astonishment.

Another speaks in the ear of his neighbour, and he who listens turns towards him and gives him his ear, holding a knife in one hand and in the other the bread half divided by this knife.

Another as he turns holding a knife in his hand overturns with this hand a glass over the table.

Another rests his hands upon the table and stares.

Another breathes heavily with open mouth.

Another leans forward to look at the speaker and shades his eyes with his hand.

Another draws himself back behind the one who is leaning forward and watches the speaker between the wall and the one who is leaning.[1]

Forster II 62 v. and 63 r.

Cristofano da Castiglione lives at the Pietà, he has a fine head.

Forster III I v.

The Florentine morel of Messer Mariolo, a big horse, has a fine neck and a very fine head.[2]

White stallion belonging to the falconer has fine haunches, is at the Porta Comasina.

Big horse of Cermonino belongs to Signor Giulio. Forster III 88 r.

[*With drawing of foreleg with measurements*]

The Sicilian of Messer Galeazzo.

Make this the same within, with the measure of all the shoulder.

Windsor: Drawings 12294

[*With drawing of horse*]

The big jennet of Messer Galeazzo. Windsor: Drawings 12319

[These verses, presumably sent to Leonardo by an admirer of his art, are the evidence of his having painted a portrait of Lucrezia Crivelli, a lady of the Milanese Court]

[1] Description of action of figures in 'The Last Supper'.

[2] MS. *Morel fiorentino di miser Mariolo.* Morel, a dark-coloured horse (Murray). As the manuscript in which these notes occur bears references to the years 1493 and 1494 they may refer to studies for the equestrian statue of which a model was erected in the latter year.

Ut bene respondet naturae ars docta: dedisset
Vincius, ut tribuit cetera, sic animam.
Noluit, ut similis magis haec foret: altera sic est:
Possidet illius Maurus amans animam.
Hujus, quam cernis, nomen Lucretia: divi
Omnia cui larga contribuere manu.
Rara huic forma data est: pinxit Leonardus: amavit
Maurus: pictorum primus hic: ille ducum.
Naturam et superas hac laesit imagine divas
Pictor: tantum hominis posse manum haec doluit.
Illae longa dari tam magnae tempora formae:
Quae spatio fuerat deperitura brevi.
Has laesit Mauri causa: defendet et ipsum
Maurus: Maurum homines laedere diique timent.[1]

C.A. 167 v. c

[1] How well the master's art answers to nature. Da Vinci might have shown the soul here, as he has rendered the rest. He did not, so that his picture might be the greater likeness; for the soul of the original is possessed by Il Moro, her lover.

This lady's name is Lucrezia, to whom the gods gave all things with lavish hand. Beauty of form was given her: Leonardo painted her, Il Moro loved her—one the greatest of painters, the other of princes.

By this likeness the painter injured Nature and the goddesses on high. Nature lamented that the hand of man could attain so much, the goddesses that immortality should be bestowed on so fair a form, which ought to have perished.

For Il Moro's sake Leonardo did the injury, and Il Moro will protect him. Men and gods alike fear to injure Il Moro.

XXXVI

Sculpture

'As practising myself the art of sculpture no less than that of painting, and doing both the one and the other in the same degree.'

[*Notes made in preparation for a statue*]

Of that at Pavia[1] the movement more than anything else is deserving of praise.

It is better to copy the antique than modern work.

You cannot combine utility with beauty as it appears in fortresses and men.

The trot is almost of the nature of the free horse.

Where natural vivacity is lacking it is necessary to create it fortuitously. C.A. 147 r. b

The sculptor cannot represent transparent or luminous things. C.A. 215 v. d

All the heads of the large iron pins.[2] C.A. 216 v. a

How the eye cannot discern the shapes of bodies within their boundaries except by means of shadows and lights; and there are many sciences which would be nothing without the science of these shadows and lights: as painting, sculpture, astronomy, a great part of perspective and the like.

As may be shown, the sculptor cannot work without the help of

[1] The reference is to the antique bronze equestrian statue representing Odoacer, King of the Goths, according to the Anonimo Morelliano, Gisulf according to Antonio Campo the historian of Cremona, which was removed by Charlemagne from Ravenna to Pavia and stood in the Piazza del Duomo until the time of its destruction, which occurred in a revolutionary outbreak in 1796. It was called Regisole, the name being derived from the reflections of the sun's rays on the gilded bronze. Petrarch in a letter to Boccaccio says of it that 'it was looked upon as a masterpiece of art by all good judges'.

[2] The words are at the side of a drawing in red chalk representing a horse in an attitude of walking seen within a frame.

shadows and lights, since without these the material carved would remain all of one colour; and by the ninth of this [book] it is shown that a level surface illumined by uniform light does not vary in any part the clearness or obscurity of its natural colour, and this uniformity of colour goes to prove the uniformity of the smoothness of its surface. It would follow therefore that if the material carved were not clothed by shadows and lights, which are necessitated by the prominences of certain muscles and the hollows interposed between them, the sculptor would not be able uninterruptedly to see the progress of his own work, and this the work that he is carving requires, and so what he fashioned during the day would be almost as though it had been made in the darkness of the night.

OF PAINTING

Painting, however, by means of these shadows and lights comes to represent upon level surfaces scenes with hollows and raised portions, separated from each other by different degrees of distance and in different aspects. C.A. 277 v. a

Measurement of the Sicilian [horse], the leg behind, in front, raised and extended. C.A. 291 v. a

OF STATUES

If you wish to make a figure of marble make first one of clay, and after you have finished it and let it dry, set it in a case, which should be sufficiently large that—after the figure has been taken out—it can hold the block of marble wherein you purpose to lay bare a figure resembling that in clay. Then after you have placed the clay figure inside this case make pegs so that they fit exactly into holes in the case, and drive them in at each hole until each white peg touches the figure at a different spot; stain black such parts of the pegs as project out of the case, and make a distinguishing mark for each peg and for its hole, so that you may fit them together at your ease. Then take the clay model out of the case and place the block of marble in it, and take away from the marble sufficient for all the pegs to be hidden in the holes up to their marks. and in order to be able to do this better, make the case so that the whole of it can be lifted up and the bottom may still remain under the marble; and by this means you will be able to use the cutting tools with great readiness. A 43 r.

OF THE BLOW OF SCULPTORS

Because the time of the blow is indivisible, like the contact caused by this blow, its operation is of such swiftness that time does not permit this blow to transfer itself to the foundations of the things struck with sufficient swiftness to prevent the blow being already dead in its upper parts, like the mason who breaks a stone in his hand with a hammer without violence or damage to the hand.

And this is why, after the iron *a b* has been struck by the blow of the hammer in its upper part *a*, this part has obeyed the nature of the blow rather than transferred it to its base *b*, so that the extremity is enlarged more than the base.

And from this it follows that sculptors work to better effect upon their marbles when they rough-hew with a pointed hammer than with a chisel struck by the hammer.

A sharp sword will also cut a roll in the air. C 6 v.

[*Sculpture*]

When you have finished building up the figure you will make the statue with all its surface measurements. Quaderni III 3 r.

Some have erred in teaching sculptors to surround the limbs of their figures with wires, as though believing that these limbs were of equal roundness at each part at which they were surrounded by these wires. Quaderni VI 10 r.

XXXVII

Casting

'Of the horse I will say nothing because I know the times.'

. . . the cold will have sufficient thickness to touch the plaster, and you pour out the rest and fill with plaster and then break the mould, and put the iron pins across, boring through the wax and plaster, and then clean the wax at your leisure; afterwards put it in a case, and put a mould of plaster over it, leaving the air holes and the mouth for the casting. Through this mouth turn the mould upside down, and after it has been heated you will be able to draw out the wax contained within it; and you will be able to fill up the vacuum which remains with your liquefied material, and the thing cast will become hollow. But in order to prevent the plaster from becoming broken while being rebaked you must place within it what you know of. C.A. 352 r. c

[*With drawing of apparatus*]

This is the way in which the forms rapidly dry and are continually turned like roasts. Tr. 29 a

HOW CASTS OUGHT TO BE POLISHED

You should make a bunch of iron wire as thick as fine string and scrub them with it with water, but keeping a tub beneath so that it may not cause mud below.

HOW TO REMOVE THE ROUGH EDGES OF THE BRONZE

You should make an iron rod which may be of the shape of a large chisel, and rub it along the edges which remain upon the casts of the guns and which are caused by the joins in the mould; but see that the rod is a good weight and let the strokes be long and sweeping.

TO FACILITATE THE MELTING

First alloy part of the metal in the crucible and then put it in the furnace: this being in a molten state will make a beginning in the melting of the copper.

TO GUARD AGAINST THE COPPER COOLING IN THE FURNACE

When the copper begins to cool in the furnace proceed instantly as soon as you see this to slice it up with a stirring pole while it is in a paste, or if it has become entirely cold, cut it as you would lead with broad large chisels.

FOR THE MAKING OF A LARGE CAST

If you have to make a cast of a hundred thousand pounds, make it with five furnaces with two thousand pounds for each, or as much as three thousand pounds at most. Tr. 47 a

HOW THE BOARD SHOULD BE PLACED WHICH SUPPORTS THE MORTAR

The board that serves as a guide to the shape of the mortar ought therefore to be reduplicated from the centre backwards by the breadth of a great plank, to the end that it should not become twisted, and where this board has the impress of the frames and form of the cannon is the face not the edge, and when you add the tallow burnish this face with a pig's tooth so that it may be solid, and let the tallow be finely strained in order that as it turns it may not make marks.

WHAT TO DO IN ORDER TO BREAK UP A LARGE MASS OF BRONZE

If you wish to break a large mass of bronze suspend it first, then make a wall round it on the four sides in the shape of a hod for bricks, and make a great fire there; and when it is quite red-hot give it a blow with a great weight raised above it and do this with great force.

[*With two sketches*]

OF CASTING MANY SMALL CANNON AT THE SAME TIME

Make the courses for the bronze as is shown here just now; and keep *d b c* stopped up, but leave the course *a* entirely open; and when that is full unstop *b*, and when that is full unstop *c*, and then *d*; and the door of the courses should be of brick, the thickness of three fingers and well covered with ashes and then it is opened with the pincers; and branches of the courses when they also are cast ought to be divided with small plates of iron covered with earth before they are fastened.

Tr. 48 a

HOW TO MAKE LEAD COMBINE WITH OTHER METAL

If you wish for the sake of economy to put lead with the metal, and in order to lessen the amount of the tin which is necessary, first alloy the lead with the tin and then put above the molten copper.

OF A NECESSITY FOR MELTING IN A FURNACE

The furnace should be between four pillars with strong foundations.

OF THE THICKNESS OF THE COATING

The coating ought not to exceed the thickness of two fingers, and it ought to be laid on in four thicknesses over the fine clay and then well prepared, and it should be annealed only on the inside and then given a fine dressing of ashes and cattle dung.

OF THE THICKNESS OF THE MORTAR

The mortar ought to carry a ball of six hundred pounds and more, and by this rule you will take the measure of the diameter of the ball and divide it in six parts, and one of these parts will be its thickness at the muzzle, and it will always be half at the breech. And if the ball is to be of seven hundred pounds one seventh of the diameter of the ball will be its thickness at the muzzle, and if the ball is to be eight hundred it will be the eighth of its diameter at the muzzle, and if nine hundred one eighth and one half of it, and if one thousand one ninth.

OF THE LENGTH OF THE TUBE OF THE MORTAR

If you wish it to throw a ball of stone, make the length of the tube as six or up to seven times the diameter of the ball; and if the ball is to be of iron make this tube up to twelve times the ball, and if the ball is to be of lead make it up to eighteen times. I mean when the mortar is to have its mouth fitted to receive within it six hundred pounds of stone ball and over.

OF THE THICKNESS OF SMALL CANNON

The thickness of small cannon at the muzzle ought not to exceed from a third to a half of the diameter of the ball, nor the length from thirty to thirty six times its diameter. Tr. 49 a

OF LUTING THE FURNACE ON THE INSIDE

The furnace ought before you put the metal in it to be luted with earth from Valenza, and over that ashes.

OF RESTORING THE METAL WHEN IT SEEMS ON THE POINT OF COOLING

When you see that the bronze is on the point of becoming congealed take wood of the willow cut into small chips and make up the fire with it.

THE CAUSE OF ITS CONGEALING

I say the cause of this congealing is often derived from there being too much fire and also from the wood being only half-dried.

TO KNOW THE CONDITION OF THE FIRE

You will know when the fire is good and suitable by the clear flames, and if you see the points of these flames turbid and ending in much smoke do not trust it, and especially when you have the molten metal almost in fluid state.

WHAT KINDS OF WOOD ARE SUITABLE

Wood is suitable when it is the young willow, or if willow cannot be procured get alder, and let each branch be young and well dried.

OF ALLOYING THE METAL

The metal used for bombards must invariably be made with six or even eight parts to a hundred, that is six parts of tin to one hundred of copper, but the less you put in the stronger will be the bombard.

WHEN THE TIN SHOULD BE ADDED TO THE COPPER

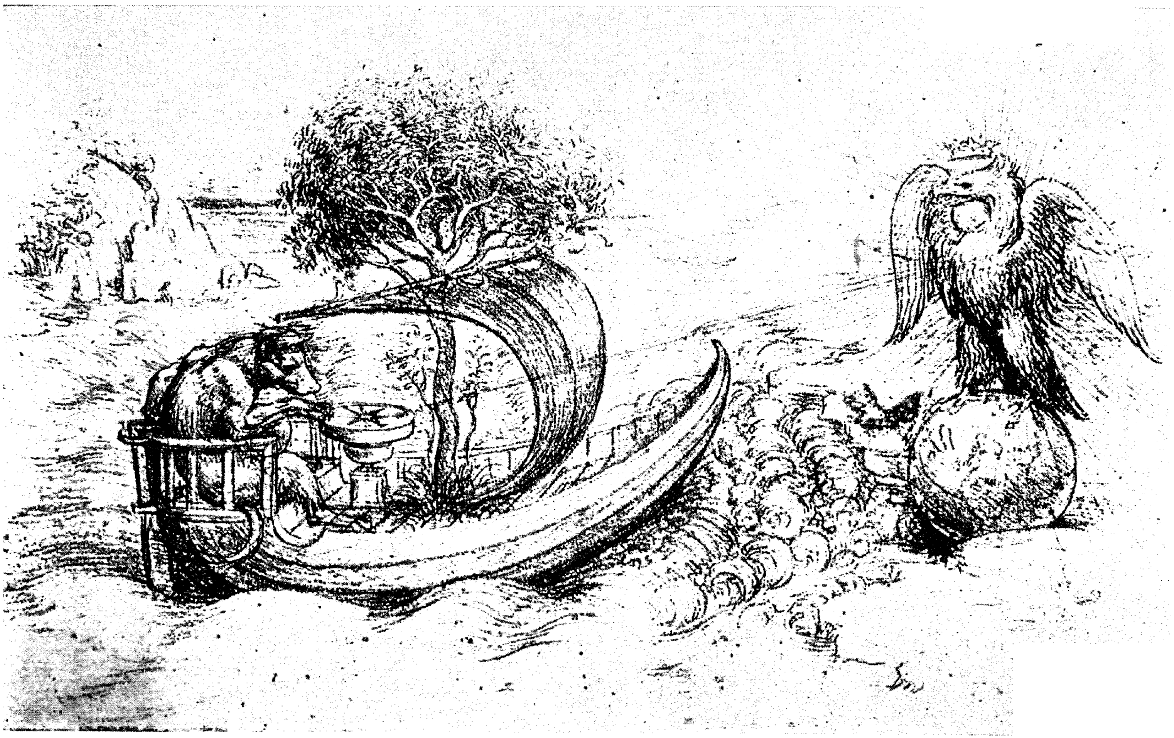
The tin should be put with the copper when you have the copper changed into a fluid state.

HOW THE PROCESS OF MELTING MAY BE EXPEDITED

You can expedite the process of melting when the copper is two-thirds changed to a fluid state. With a chestnut rod you will then be able frequently to manage to stir the remainder of the copper which is still in one piece amid the melted part. Tr. 50 a

THE FINE EARTH OF THE BOMBARDS

Take the dust of wool clippings and fix it on a wall in thin plaster so that it drives well. Then pound it and sift in fine powder, and to fifty parts of this powder add ten parts of brick, not over-baked and well pounded and sifted, also a small quantity of fine wool clippings or fustian cloth; and then to this compound add six parts of ashes which you will sift when moistened with water well salted; and this you will apply liquid and thin two or three times with a plasterer's brush, leaving it every time to dry without fire. Also it would be advisable to add first to this mixture ashes of burnt ox-dung moistened with salt water.



ALLEGORY OF CONCORDAT (December, 1515) BETWEEN FRANCIS I AND LEO X (*See* Popp: *Leonardo Zeichnungen*)
Royal Library, Windsor

OF THE TALLOW

The tallow ought to be applied mixed with soot from a blacksmith, and as fine as you can, or if you desire ashes of ox-dung.

OF THE FRAMES

The frames should be made almost to the limit of the cord as though [one were winding] a peg-top, and above this the frames should be completed with fine earth and polished with the said tallow and soot, and the ornaments should be of wax.

THE FRAME

The frame of the tail ought to have as its final covering a square in which are brickdust and ashes with salt water. Or it is even better to apply ashes of ox-dung with salt water over the said frame.

OF DIRECTING THE FRAME

The frame should first be put in the trench with grappling-hooks as you saw before, then annealed little by little, emerging in the manner somewhat of the colour of brick (*di poi lau [?] con uno negnietto*) striking softly bit by bit, and where you hear it resound bind with iron wire, but in order not to go astray place it to turn everywhere.

EARTH SUITABLE FOR GENERAL USE

The earth to be generally used ought to be that of which bricks are made, mixed with ox-dung or clippings of woollen cloth. Tr. 51 a

The bottom of the stove, three rows of unbaked bricks of ordinary clay and an inch and a half of ashes, the vault one layer of unbaked bricks of Valenza clay and another layer of baked bricks.

Loose earth [?] [1] should be put with the ashes.

The wood of the frame of the bombards should be covered an inch deep in cinders.

[1] MS. *i calossi*
Hoare's Ital. Dict. art. *loscio* has *terra loscia*, loose earth.

The mouth of the stove, that is where the flame enters, ought to be of large bricks of Valenza clay.

Each of two flues ought to be for the half of the window for the entrance of the flame. Tr. 54 a

NOTES ON USE OF 'SAGOMA'[1]

Let the plumb-line be extended in two directions opposite to the centre of the poles *a c*, and let the plane surface be formed of plaster (MS. *osseg* = *gesso*) little by little under the movement of the 'sagoma'.

And when the pavement is entirely finished the whole should be corrected again minutely with the 'sagoma'; and this 'sagoma' when used on the prepared surface (MS. *otasseg* = *gessato*) should be used with the greatest possible care. G 14 r.

[*Of friction of the sagoma*]

The friction of the polishing instrument against its surface ought not to be done with the edge of the instrument, except when first preparing the said surface. But when it is necessary to refine this surface then the instrument ought not to be of less width than half the surface. This may be proved: suppose *f e d c* to be the said polishing instrument and *f e n m* the smoothed surface. I maintain that if this polishing instrument were to have only one cutting edge, as in *d c* with *a b*, it would have far greater weight when the perpendicular line was upon the part *d c* of the smoothed surface than when it was on the position *f e* of the said surface. And for this reason it would wear away the rubbed parts much more if it were straight than if it were slanting. And the concaveness of this surface would be unequal, such inequality as cannot be formed by the great contact of the polishing instrument with the surface which it polishes.

But it would be better that the instrument and the surface should be the equal the one of the other, for when one of the sides of the instrument was in the middle of the said surface its extremity would receive all the accidental weight of this instrument.

[1] A mould, also 'an instrument for smoothing and polishing a surface'—Ravaisson-Mollien.

But the polishing instrument with one cutting edge is necessary, merely in order to give the form to its smoothed surface by means of three or four movements, which should make it entirely perfect.

G 16 r.

The cogs that cause the movement of the *sagoma* set in their grooves. G 37 r.

The *sagoma* should be as that used on the road of Fiesole—with water.

Because it is necessary that in proportion as the said instrument is lowered so it wears itself away, and as after having been lowered it becomes very strong it is therefore necessary to make the pulleys with nuts so that screws turn within them, and that it shuts and opens between *a c* as *b* shows between *a c*, and that these rings which form nuts for the screws should be drawn with the cords *d e f g*. G 43 v.

VARNISH OF THE FIRED SURFACE [1]

Mercury with Jupiter and Venus: [2] after the paste has been made it should be worked upon the *sagoma* continully until Mercury is entirely separated from Jupiter and Venus. G 46 v.

USE OF THE SAGOMA

Let the concavity be pressed with the instrument first several times backwards and forwards before it is varnished, then the varnish should be applied to the moist surface, and go over it with the sieve; use the mould two or three times, then expose it to the furnace, and when it acquires lustre immediately apply the mould while it is hot.

The centre of the revolution of the mould upon the structure ought to be fixed, and such that it can be raised and lowered, and moved forward and backward, so that its . . . falls upon the centre of the mould.

The base of the oven should be of the same shape as that of the object placed in the oven; and it is well that it should be of one piece

[1] *Vernicie della igna.*

[2] i.e., according to Richter, quicksilver with iron and copper.

of tufa stone, so that it can resist like an anvil the transverse percussion of the heavy mould which strikes it. G 47 r.

Let the wood of the *sagoma* be well covered over with pitch (MS. *otaicepni* = *inpeciato*) so that it may not bend. G 51 v.

In the polishing instrument there is a space left in order to be able to insert the lead moulding, and so that one may be able to change these from time to time as they are consumed. And so with the emery, one will guide the 'male' of the fired surface to perfection, and upon this one will afterwards print the copper (MS. *emar* = *rame*) after it has been made absolutely smooth.

N, surface, is of Saturn[1] and it serves for the process of smoothing conjoined with the motive power, *m* below, in margin.

The motive power is Neptune.

This will keep the object to be polished below and the polishing instrument above; and the pole will find itself above, and so this pole not being weighed down as is that of the instrument represented above will come to maintain itself, and as it is not able to consume itself the process will be complete.

Moreover the thing polished will support above itself the substance which polishes it, and the polishing instrument being of lead may be recast and adjusted many times.

The mould may be of Venus, Jupiter or Saturn, and often cast back into the lap of its mother, and it may be worked over with fine emery; and the mould may be of Venus and Jupiter plastered over Venus.

But first you will put to the test Venus and Mercury mixed with Jupiter, and manage so that Mercury may escape, and then roll them up tightly so that Venus and Jupiter become blended in Neptune as thinly as possible.

[*Figure*]

This ought to be upside down, in order that the mould may weigh upon the surface it treats with a perpendicular weight. Thus the centre of the object in circumvolution will not consume itself, in order not to have the weight upon itself; and apart from this the polishing process will serve to receive and support it, as I have said in the first instance. G 53 r.

[1] Lead, Richter.

HOW TO MAKE A CURVE WHICH LEAVES THE PLATE PARALLEL PRECISELY

Have a frame of stout walnut wood upon which build a square frame with raised centering, and upon this are fixed both ends of the drawn plate, which is separated at the end from the sides of the wall, carrying and holding with it all the plates that are nailed above. And this frame should always be with the above-mentioned dark plates.

G 74 V.

STUCCO

Cover with stucco the boss of the . . . (*ingnea?*) of plaster, and let this be made of Venus and Mercury[1] and smear this boss well over with a uniform thickness of the blade of a knife, doing it with a rule (*sagoma?*) and cover this with the body of a bell so that it may drip, and you will have again the moisture with which you formed the paste: dry the rest well and then fire it, and beat or burnish it with a good burnisher, and make it thick towards the side.

Powder the glass to a paste with borax and water, and make stucco; then drain it off so as to dry it, then varnish it with fire so that it shines well. G 75 V.

If you wish to make a large thin metal plate of lead, make a smooth level surface and fill it with glowing coals and melt lead in it, and then with a smooth rake take away the coals and allow it to cool and it is made. Forster II 46 v.

When you wish to cast in wax burn off the scum with a candle and the cast will come without holes.

Grind verdigris with rue many times together with juice of lemon and keep it from Naples yellow. Forster II 64 v.

The steel is first beaten well for the length, then broken in squares, and these are placed one above another and well covered with earth of Valenza and powdered talc, and it is dried over a slow fire and gradually heated; and when it has been thoroughly heated both inside

[1] Ingnea, Venus and Mercury are written backwards in the text, i.e. they appear as aengni, erenev and oirucrem. Dr. Richter suggests that Venus and Mercury may mean 'marble' and 'lime' of which stucco is composed.

and out then the fire exerts its force and makes it become molten. But first insert flakes of iron, then have the earth gradually removed and beat it lengthwise; and this is good steel. Forster III 33 v.

Dry earth sixteen pounds; a hundred pounds of metal; moistened earth twenty; moisten the hundred of metal which adds four pounds of water; one of wax, one pound of metal somewhat less; cloth clippings with earth measure for measure. Forster III 36 v.

Two ounces of plaster to a pound of metal; [oil of] walnut eases it at the curve. Forster III 37 r.

TO MAKE A PLASTER CAST FOR BRONZE

Take for every two cupfuls of plaster one of burnt ox-horn, and mix them together and make the cast. Forster III 39 v.

FOR CASTING

Tartar burnt and powdered with plaster and used in casting causes such plaster to adhere together when it is annealed; then it is dissolved in water. Forster III 42 v.

For mirrors, thirty of tin upon a hundred of copper; but first clarify the two metals and plunge them in water and granulate them, and then fuse the copper and put it upon the tin. Forster III 87 v.

MOULD OF THE HORSE

Make the horse upon legs of iron, strong and firm in a good foundation. Then rub it with tallow and give it a good coating, letting it dry thoroughly layer by layer. And by this you will increase its thickness by the breadth of three fingers. Then fix and bind it with iron according to need. Besides this hollow out the mould, then get it to the required thickness, and then fill up the mould again by degrees and continue until it is entirely filled. Then bind it round with its irons and strap it up, and anneal it on the inner side where it has to touch the bronze.

OF MAKING THE MOULD IN PIECES

Mark upon the horse when finished all the pieces of the mould with which you wish to cover the horse, and after the clay has been laid on cut it to correspond in every piece, so that when the mould is finished you can take it off and then replace it in its first position with its catches by the countersigns.

The square block *a b* will go between the cover and the core, that is in the hollow space where the liquefied bronze is to be; and these square blocks of bronze will keep the spaces between the mould and the cover at an equal distance, and for this reason these blocks are of great importance.

The clay must be mixed with sand.

Take wax to give back and to pay for what has been used.

Dry one layer after another. Make the outer mould of plaster in order to save time in drying and the cost of wood; and with this plaster fasten the iron bands outside and inside for a thickness of two fingers; make terra cotta.

And this mould you will take a day to make; half a boat-load of plaster will serve you.

Good.

Stop it up again with paste and clay, or white of egg and brick and rubble. Windsor: Drawings 12347 r.

Three irons which bind the mould [1]

If you wish to make casts rapidly and simply, make them with a box of river sand moistened with vinegar.

After having made the mould upon the horse you will make the thickness of the metal in clay.

Note in alloying how may hours are needed for each hundredweight. In casting each keep the furnace with its fire closed up. Let all the inside of the mould be saturated with linseed oil or turpentine. Then take a handful of powdered borax and hard rosin with aqua vitae and put a coat of pitch over the mould so that while underground the damp may not [injure it?].

In order to manage the large mould make a model of the small mould; make a small room in proportion.

[1] I have followed Richter's order of arrangement in this passage.

Make the vents in the mould while it is upon the horse.

Hold the hoofs in tongs and cast them with fish-glue.

Weigh the parts of the mould to find out what amount of metal it will take to fill them, and give so much to the furnace that it may supply each part with its quantity of metal; and this you will ascertain by weighing the clay of that part of the mould to which the quantity in the furnace has to correspond. And this is done so that the furnace that is for the legs fills them and does not have to supply metal for the head from the legs which would be impossible.

Cast at the same casting as the horse the little door (*sportello*) of the . . . . Windsor: Drawings 12350

XXXVIII

Architecture

'If anyone wishes to go through the whole place by the high-level roads, he will be able to use them for this purpose, and so also if anyone wishes to go by the low-level roads.'

IF THE usual width of the river is that of one arch construct this bridge with three, and do this in order to allow for the floods.

C.A. 46 V. a

[*Ground-plan of castle with lake and boats on it*]

[*The palace of the prince ought to have a piazza in front*] [1]

The rooms which you mean to use for dancing or to make different kinds of jumps or various movements with a crowd of people, should be on the ground floor, for I have seen them collapse and so cause the death of many. And above all see that every wall, however thin it may be, has its foundations on the ground or on well-planted arches.

Let the mezzanines of the dwellings be divided by walls made of narrow bricks, and without beams because of the risk of fire.

All the privies should have ventilation openings through the thickness of the walls, and in such a way that air may come in through the roofs.

Let the mezzanines be vaulted, and these will be so much the stronger as they are fewer in number.

Let the bands of oak be enclosed in the walls to prevent them from being damaged by fire.

Let the privies be numerous and be connected one with another, so that the smell may not spread through the rooms, and their doors should all close automatically.

[*Plans*] Kitchens. Pantry.

[1] Words crossed out in MS.

[*Plans*] Kitchens. Stable. Eighty braccia wide and a hundred and twenty braccia long in ground plan. Combats by means of the boats, that is the combatants may be upon the boats. Ditch forty braccia. Road below.

At the angle *a* should be the keeper of the stable.

The largest division of the front of this palace is in two parts, that is the width of the court is half the length of the aforesaid front.

C.A. 76 v. b

[*With plan*]

Stable for the Magnifico, for the upper part, one hundred and ten braccia long and forty braccia wide.

[*With plan*]

Stable for the Magnifico, for the lower part, one hundred and ten braccia long, and forty braccia wide, and it is divided into four rows for horses, and each of these rows is divided into thirty-two spaces, called intercolumnar, and each intercolumnar space has a capacity for two horses, between which is interposed a swing-bar.

This stable therefore has a capacity for a hundred and twenty-eight horses. C.A. 96 v. a

[*Town-planning*]

Give me authority whereby without any expense to you it may come to pass that all the lands obey their rulers, who . . .

The first renown will be eternal together with the inhabitants of the city built or enlarged by him.

Let the bottoms of the reservoirs which are behind the gardens be as high as the level of the gardens, and by means of discharge-pipes they will be able to bring water to the gardens every evening every time that it rises, raising the joint half a braccio; and to this let the senior officials be appointed.

[*With plan*] Canal. Weir. Garden.

And nothing is to be thrown into the canals, and every barge is to be obliged to carry away so much mud from the canal, and this is afterwards to be thrown on the bank.

[*With plan*] Construct in order to dry up the canal and to clean the (lesser) canals.

All people obey and are swayed by their magnates, and these magnates ally themselves with and are constrained by their lords in two ways, either by blood-relationship or by the tie of property; blood-relationship when their sons, like hostages, are a surety and a pledge against any suspicion of their faith; the tie of property when you let each of them build one or two houses within your city, from which he may draw some revenue; and [*in addition to this*][1] he will draw from ten cities of five thousand houses with thirty thousand habitations, and you will disperse so great a concourse of people, who, herding together like goats one upon the back of another filling every part with their stench, sow the seeds of pestilence and death.

And the city will be of a beauty equal to its name, and useful to you for its revenues and the perpetual fame of its growth.

The municipality of Lodi will bear the expense, and keep the revenue which once a year it pays to the Duke.

To the stranger who has a house in Milan it will often befall that in order to be in a more imposing place he will go and live in his own house; and whoever is in a position to build must have some store of wealth, and in this way the poor people will become separated by such settlers, and when these . . . assessments will increase and the fame of its greatness. And even if he should not wish to reside in Milan he will still remain faithful, in order not to lose the profit of his house at the same time as the capital. C.A. 65 v. b

[*Architectural drawings: ground plans*]

Buttery. Kitchen. Family.

He who is stationed in the buttery ought to have behind him the entrance to the kitchen, in order to be able to do his work expeditiously; and the window of the kitchen should be in the front of the buttery so that he may extract the wood.

The drawing that I have made has a larger façade behind than in front, whereas it should be the opposite.

The large room for the family away from the kitchen, so that the master of the house may not hear their clatter; and the kitchen may be convenient for washing the pewter so that it may not be seen being carried through the house.

[1] Words crossed out in MS.

Large room for the master. Room. Kitchen. Larder. Guard Room. Large room for the family.

Larder, logs, kitchen and hen-coop (? *pollaro*) and hall, and the apartment will be or ought to be in contact for the convenience that ensues; and the garden and stable, manure and garden, in contact. The large room for the master and that for the family should have the kitchen between them, and in both the food may be served through wide and low windows, or by tables that turn on swivels.

The wife should have her own apartment and hall (*sala*) apart from that of the family, so that she may set her serving-maids to eat at another table in the same hall. She should have two other apartments as well as her own, one for the serving-maids the other for the wet nurses, and ample space for their utensils.

I wish to have one door to close the whole house. C.A. 158 v. a

The hall for the festival should be situated so that you come first into the presence of the lord, and then of the guests, and the passage should be so arranged that it enables you to enter the hall without passing in front of the people more than one may wish; and over on the other side opposite to the lord should be situated the entrance of the hall and a convenient staircase, which should be wide, so that the people in passing along them may not push against the masqueraders and damage their costumes, when going out . . . the crowd of men . . . with such masks . . . this hall . . . two rooms side by side . . . right double . . . of this an exit . . . collection and one for the masqueraders. C.A. 214 r. b

[*A plan for laying out a water-garden*]

The staircase is one braccio and three quarters wide and it is bent like a knee, and altogether it is sixteen braccia with thirty two steps half a braccio wide and a quarter high; and the landing where the staircase turns is two braccia wide and four long, and the wall which divides one staircase from the other is half a braccio; but the breadth of the staircase will be two braccia and the passage half a braccio wider; so that this large room will come to be twenty-one braccia long and ten and half braccia wide, and so it will serve well; and let us make it eight braccia high, although it is usual to make the height tally with the width; such rooms however seem to me depressing for they are always somewhat in shadow because of their great height, and the staircases would then be too steep because they would be straight.

By means of the mill I shall be able at any time to produce a current of air; in the summer I shall make the water spring up fresh and bubbling, and flow along in the space between the tables, which will be arranged thus [*drawing*]. The channel may be half a braccio wide, and there should be vessels there with wines always of the freshest, and other water should flow through the garden, moistening the orange trees and citron trees according to their needs. These citron trees will be permanent, because their situation will be so arranged that they can easily be covered over, and the warmth which the winter season continually produces will be the means of preserving them far better than fire, for two reasons: one is that this warmth of the springs is natural and is the same as warms the roots of all the plants; the second is that the fire gives warmth to these plants in an accidental manner, because it is deprived of moisture and is neither uniform nor continuous, being warmer at the beginning than at the end, and very often it is overlooked through the carelessness of those in charge of it.

The herbage of the little brooks ought to be cut frequently so that the clearness of the water may be seen upon its shingly bed, and only those plants should be left which serve the fishes for food, such as watercress and other plants like these.

The fish should be such as will not make the water muddy, that is to say eels must not be put there nor tench, nor yet pike because they destroy the other fish.

By means of the mill you will make many water-conduits through the house, and springs in various places, and a certain passage where, when anyone passes, from all sides below the water will leap up, and so it will be there ready in case anyone should wish to give a shower-bath from below to the women or others who shall pass there.

Overhead we must construct a very fine net of copper which will cover over the garden and shut in beneath it many different kinds of birds, and so you will have perpetual music together with the scents of the blossom of the citrons and the lemons.

With the help of the mill I will make unending sounds from all sorts of instruments, which will sound for so long as the mill shall continue to move. C.A. 271 v. a

[*The dimensions of a temple*]

You ascended by twelve flights of steps to the great temple, which is eight hundred feet in circumference and is built in the shape of an octagon. At the eight corners were eight large plinths a braccio and a half in height and three in width and six in length at the base, with an angle in the centre which served as the foundation for eight large pillars that rose to a height of twenty-four braccia above the base of the plinth, and on top of these stood eight capitals three braccia each [in length] and six wide. Above these followed architrave, frieze and cornice, four braccia and a half in height, carried on in a straight line from one pillar to another, and thus it surrounded the temple with a circuit of eight hundred braccia; between each of the pillars, as a support to this entablature, there stood ten large columns of the same height as the pillars, three braccia thick above their bases which were one braccio and a half in height.

You ascended to this temple by twelve flights of steps, the temple being upon the twelfth, built in the shape of an octagon, and above each angle rose a large pillar, and between the pillars were interposed ten columns of the same height as the pillars, which rose twenty-eight and a half braccia above the pavement. At this same height were placed architrave, frieze and cornice, which formed a circuit round the temple, eight hundred braccia in length and of uniform height. Within this circuit at the same level towards the centre of the temple at a distance of twenty-four braccia rise pillars and columns, corresponding to the eight pillars of the angles and the columns placed in the façade. And they rise to the same height as those already mentioned, and above these pillars the continuous architrave goes back towards the pillars and columns first spoken of. C.A. 285 r. c

Our ancient architects or such . . . commencing first of all with the Iti, who according to the discourses of Diodorus Siculus were the first builders and constructors of great cities, and of fortresses and buildings both public and private which had distinction, nobility and grandeur; and by reason of this their predecessors beheld with amazement and

stupefaction the lofty and immense engines which seemed to them . . .
C.A. 325 r. b

An inverted arch is better for making a support than an ordinary one, because the inverted arch finds a wall below it which resists its weakness, while the ordinary arch finds where it is weakest nothing but air. Tr. 13 a

WHAT IS AN ARCH?

An arch is nothing other than a strength caused by two weaknesses; for the arch in buildings is made up of two segments of a circle, and each of these segments being in itself very weak desires to fall, and as the one withstands the downfall of the other the two weaknesses are converted into a single strength.

OF THE NATURE OF THE WEIGHT IN ARCHES

When once the arch has been set up it remains in a state of equilibrium, for the one side pushes the other as much as the other pushes it; but if one of the segments of the circle weighs more than the other the stability is ended and destroyed, because the greater weight will subdue the less. A 50 r.

[*With architectural drawing and plan*]

Ground plan of the pavilion which is in the middle of the labyrinth of the duke of Milan.

Pavilion of the garden of the duchess of Milan.[1]

[*With plan and drawing of fortification*]

GROUND PLAN OF RAVELIN

With this square bastion you should make only two towers in order that having . . . that one may not impede the other; and at each tower you should make a bridge entering into the ravelin as is shown in the

[1] A document recently found at Como bearing the date March 28, 1490, consists of a contract for the supply of stone for a pavilion which 'Maestro Lionardo painter and architect' was to construct in Milan.

drawing. The diameter of the square bastion should be a hundred braccia, and the diameter of each tower should be thirty braccia.

The ravelins should be open within so that being so the enemy cannot maintain himself there, but is exposed to attack from the towers.

B 12 r.

[*With architectural drawing*]

If you have your family in your house, make their habitations in such a way that at night neither they nor the strangers to whom you give lodging are in control of the egress of the house; in order that they may not be able to enter in the habitation where you live or sleep, close the exit *m*, and you will have closed the whole house. B 12 v.

[*With drawing of section of wall of a house*]

C is a stove which receives heat from the kitchen chimney by means of a copper flue two braccia high and one wide, and a stone is put over the place in summer in order that it may be possible to use the stove; *b* will be the place for keeping salt, and at the division *a* there will be an opening of a passage into the chimney for hanging up salted meats and such like things; and in the ceiling there will be many flues for the smoke, with different exits at the four sides of the chimney, so that if the north wind should begin to be troublesome the smoke may find an outlet on the other side. And the smoke proceeds to spread itself through the numerous flues and to cure salted meats; tongues and sausages and things like these it brings to perfection. But see to it that when you push the small door *a* a window opposite opens, which gives light to the little room; and this will be done by means of a rod joined to the door and the window in this way. B 14 v.

[*With ground plan of fortress*]

A way of a fortress with double moat. And the spurs which pass from the principal wall to the Garland serve two uses: that is they form a buttress and they help in part to render it possible to defend the base of the Garland when the principal wall has been thrown down.

B 15 r.

[*Note with plan of section of town showing high- and low-level roads*]

The roads [marked] *m* are six braccia higher than the roads [marked] *p s*, and each road ought to be twenty braccia wide and have a fall of half a braccio from the edges to the centre. And in this centre at every braccio there should be an opening one braccio long and of the width of a finger, through which rain-water may drain off into holes made at the level of the roads *p s*. And on each side of the extremity of the width of this road there should be an arcade six braccia broad resting on columns. And know that if anyone wishes to go through the whole place by the high-level roads, he will be able to use them for this purpose, and so also if anyone wishes to go by the low-level roads.

The high-level roads are not to be used by waggons or vehicles such as these but are solely for the convenience of the gentlefolk. All carts and loads for the service and convenience of the common people should be confined to the low-level roads.

One house has to turn its back on another, leaving the low-level road between them. The doors *n* serve for the bringing in of provisions such as wood and wine and suchlike things. The privies, the stables and suchlike noisome places are emptied by underground passages, situated at a distance of three hundred braccia from one arch to the next, each passage receiving its light through the openings in the streets above. And at every arch there should be a spiral staircase; it should be round because in the corners of square ones nuisances are apt to be committed. At the first turn there should be a door of entry into the privies and public urinals, and this staircase should enable one to descend from the high-level to the low-level road.

The high-level roads begin outside the gates, and when they reach them they have attained a height of six braccia. The site should be chosen near to the sea or some large river, in order that the impurities of the city which are moved by water may be carried far away.

B 16 r. and 15 v.

[*Architectural*]

The earth which is dug out from the cellars ought to be raised at one side so as to construct a terrace garden at the same level as the hall; but see that between the earth of the terrace garden and the wall of the house there is an intervening space, so that damp may not spoil the principal walls.

B 19 v.

[*With drawing and ground plan of church*]

This edifice is inhabited both in the upper and in the lower part. The entrance to the upper part is by way of the campaniles, and it goes along the level on which rest the four drums of the dome, and the said level has a parapet in front of it. And none of these drums communicates with the church but they are entirely separate. B 24 r.

Let the street be as wide as the universal height of the houses. B 36 r.

[*Castle of Milan*]
[*With drawing*]

The moats of the castle of Milan within the Garland are thirty braccia; the ramparts are sixteen braccia high and forty wide, and this is the Garland.

The outer walls are eight braccia thick and forty high, and the inner walls of the castle are sixty braccia, which would please me entirely if it were not that I should wish to see that the bombardiers who are in the walls of the Garland do not issue forth in the secret inner way, that is in *S*, but lower themselves one at a time as appears in *m f*.

Since good bombardiers always aim at the embrasures of fortresses, and can if they break a single embrasure in the said Garland enter like cats through this breach and make themselves masters of all the towers, walls, and secret passages of the Garland, therefore if the embrasures are *m f* and it shall come about that a mortar bursts one of these embrasures and the enemy enters within, they will not be able to pass farther but may be beaten back and driven away by a soldier stationed in the machicolations above; and the passage *f* ought to be continued through all the walls from three quarters downwards and without having any exit above, either in the walls or the towers, except that by which one enters, which will have its beginning within the fortress; and the above-mentioned secret passage *f* ought not to have any airhole on the outside but to get its light on the side of the fortress through the frequent loopholes. B 36 v.

HOW TO MAKE A CLEAN STABLE

[*With drawing*]

The way in which one should construct a stable: you will first divide its width in three parts, its length does not matter; and these three divisions should be equal, each being six braccia wide and ten high. The centre part should be for the use of the master of the stable, the two at the sides for the horses, each requiring for width three braccia and for length six braccia, and being half a braccio higher in front than behind.

The manger should be two braccia from the ground, the beginning of the rack three braccia, and the top of it four braccia.

To attempt however to keep my promise, namely to make the said place contrary to the usual custom clean and neat: as to the upper portion of the stable, that is, where the hay is, this part should have at its outer end a window six [? braccia] high and six wide, by which hay can easily be brought up to the loft as is shown in the machine *E*; and this should be erected in a place six braccia in breadth and as long as the stable, as is shown in *K p*. The other two parts, which have the first between them, are each divided into two parts. The two towards the hay are four braccia, and are entirely for the use and passage of the stable attendants; the other two which extend to the outside walls are two braccia, as is shown in *S R*, and these are for the purpose of giving the hay to the manger, by means of funnels narrow at the top, and broad above the mangers, so that the hay may not be stopped on the way. They should be well plastered and cleaned, as they are represented where it is marked 4 *f s*. In order that the horses may be given water the troughs should be of stone, so made as to be able to be uncovered as are boxes by raising their lids. B 39 r.

A building ought always to be detached all round in order that its true shape can be seen. B 39 v.

[*Drawing of castle showing staircases*]

Here are five staircases with five entrances; and one is not visible to another and when anyone is in one he cannot go into another; and it is a good system for those who are maintained there, in that it prevents them from mingling with each other, and being separated they will be ready for the defence of the tower: this can be either round or square. B 47 r.

[*With drawing*]

Ten spiral staircases round a tower. B 47 v.

[*With plan of ravelin*]

The ramparts placed in front of the doors of the ravelin should be solid, except for the winding staircase placed in the centre in order to connect with the battlements above, and one enters into this staircase by subterranean passages. B 49 V.

[*With drawings*]

A represents the upper church of San Sepolcro at Milan.

B is the part of it below the ground. B 57 R.

[*With drawing*]

Where you do not wish to have a portico round the whole of a courtyard, but that only one or two of the four sides should have the portico, make the others also with the same arrangement of columns, and surround the arches with an architrave on the inner side which descends as far as the bases of the columns.

And make the windows within the said architraves, and in the same way place the chief beams within the rooms in such a manner as to come between one window and the other. B 67 V.

[*With drawing*]

Double staircase. One for the commander of the castle, the other for the garrison. B 68 V.

OF ARCHITRAVES OF ONE OR MORE PIECES

Architraves of several pieces are stronger than those of merely one piece, if these pieces are so placed that their lengths point to the centre of the earth. This is proved from the fact that the stones have their marking, or vein, usually crosswise, that is in the direction of the opposite horizons of the same hemisphere, and this is the contrary to the vein, of plants which have. . . . G 52 R.

[*Of arch and support*]

The continuous quantity bent by force into a curve pushes itself in the direction of the line into which it desires to return. H 35 V.

That part of the continuous quantity will make a greater movement which is more distant from the part which moves less.

That side of the support of which the upper part is the heavier will bend in a curve towards its centre. H 36 v.

The sides of every defined quantity which has been raised in a pyramidal heap will be of the slant of the angular diameter of the perfect square. H 37 r.

[*For decorating a room*]

The narrow moulding at the top of the room—thirty lire.

For the moulding below this, I reckon each panel at seven lire, and, in expenses on azure, gold, white-lead, gypsum, indigo and size, three lire; time—three days.

The subjects under these mouldings with their pilasters, twelve lire for each.

I estimate the cost of enamel, azure and gold, and other colours at one lira and a half.

I allow five days for studying the composition, the small pilaster and other things.

Item for each small arch—seven lire.

Cost of azure and gold—three and a half lire.

Time—four days.

For the windows—one and a half lire.

The large cornice below the windows—sixteen soldi the braccio.

Item for the Roman historical compositions—fourteen lire each.

The philosophers—ten lire.

The pilasters—one ounce of azure, ten soldi.

For gold—fifteen soldi.

I estimate [this azure and gold] at two and a half lire.

H 125 [18 v.] r. and 124 [19 r.] v.

[*Drawing of church with section of ground plan*]

Both lower and upper part of this edifice are usable, as in San Sepolcro, and it is similar in its upper and lower parts except that the upper part has the cupola *c d* and the lower the cupola *a b*. As you enter the lower church you descend ten steps, and when you go up into that above you ascend twenty steps, which reckoning each as a third of a braccio comes to ten braccia. This then is the distance there is between the level of the one church and of the other.

MS. 2037 Bib. Nat. 4 r.

[*With architectural drawing*]

Here a campanile neither can nor ought to be made.

Rather must it stand separate, as it does in the cathedral, or at San Giovanni in Florence; and so also the cathedral at Pisa, for there the campanile may be seen by itself round in shape and standing apart, as also is the cathedral. And each by itself can reveal its perfection.

If however anyone should desire to make it part of the church he should make the lantern-tower serve as a campanile, as it does in the church of Chiaravalle. MS. 2037 Bib. Nat. 5 v.

Mills should not be built by stagnant water, nor by the side of the sea, because the storms choke up with sand every canal that is made upon its shores. B.M. 63 v.

[*Foundations*]

The first and most essential requisite is stability.

As regards the foundations of the component parts of temples and other public buildings, their depths should bear the same relation one to another as do the weights which are to rest upon them.

Each section of the depth of the earth in a given space is arranged in layers, the layers having each a heavier and a lighter part, the heavier being at the bottom.

This comes from the fact that these layers are formed by the sediment from the water discharged into the sea by the current of the rivers which are poured into it.

The heaviest part of this sediment was the part that was discharged first, and this process continued.

And this is the action of the water when it becomes stationary, and it is carrying it away at first where it moves.

These layers of soil are visible in the banks of rivers which in their continuous course have sawn through and divided one hill from another in a deep defile, wherein the level of the waters has receded from the shingle of the banks, and this has caused the substance to become dry and to be changed to hard stone, especially such mud as was of the finest texture. And this leads us to conclude that each part of the earth's surface was once the centre of the earth, and so conversely.

OF CRACKS IN WALLS WIDE AT THE BASE AND NARROW AT THE TOP AND THEIR CAUSE

A wall will always crack when it does not dry uniformly at the same time.

A wall of uniform thickness does not all become dry at the same time unless it is in contact with an equal medium; thus if a wall be so built that part of it touches a damp mound while the rest is exposed to the atmosphere, this latter part will become somewhat contracted while the damp portion will retain its original size.

For the part which becomes dried by the atmosphere draws itself together and shrinks, and the part in contact with the damp does not become dry, and the dry part readily breaks away from the damp part as this has not the coherence necessary for it to follow the movement of the part that is in process of becoming dry.

OF CRACKS IN THE FORM OF ARCHES WIDE ABOVE AND NARROW BELOW

Those arched cracks wide above and narrow below have their origin in walled-up doorways, which contract more in length than in width in proportion as their height is greater than their breadth, and as the joins of the mortar are more numerous in the height than in the breadth. B.M. 138 r.

When either a complete dome or a half dome is vanquished above by an insupportable weight, the vault will burst asunder, the crack being small in the upper part and broad below, and narrow on the inner side and wide on the outer side, after the manner of the skin of a pomegranate or orange which splits into many parts lengthwise, for the more it is pressed upon from the opposite ends, the wider asunder will those parts of the joints open which are farthest away from the cause of the pressure. And for this reason the arches of the vaults of any apse should never be loaded more than the arches of the building of which it forms a part, especially because that which weighs most presses most heavily upon the parts below it and drives them down upon their foundations; but this cannot happen with lighter things such as the aforesaid apses. B.M. 141 v.

Make first a treatise of the causes which bring about the collapse of walls, and then, separately, a treatise of the remedies.

Parallel cracks are constantly appearing in buildings erected in mountainous places where the rocks are stratified and the stratification runs obliquely, for, in these oblique seams, water and other moisture often penetrates, bearing with it a quantity of greasy and slimy earth; and since this stratification does not continue down to the bottom of the valleys the rocks go slipping down their slope, and never end their movement until they have descended to the bottom of the valley, carrying with them after the manner of a boat such part of the building as they have severed from the rest.

The remedy for this is to build numerous piers under the wall which is slipping away, with arches from one to another, and well-rooted [?][1] [?buttressed] and let the pillars have their bases firmly set in the stratified rock so that they may not break away.

In order to find the immovable part of the aforesaid stratum, it is necessary to sink a shaft through it to a great depth beneath the foot of the wall, and in this shaft to polish a smooth surface of the breadth of a hand from the top to the bottom of the side on which the hill slopes down. At the end of some time this smooth portion made on the side of the shaft will show very plainly which part of the mountain is moving.

B.M. 157 r.

OF STONES WHICH BECOME SEPARATED FROM THEIR MORTAR

Stones which are built up with an equal number from bottom to top and laid with an equal quantity of mortar, will settle down equally as the moisture which softens the mortar evaporates.

Cracks in walls will never be parallel unless the part of the wall which is separated from the rest does not descend.

WHAT LAW IT IS WHICH IMPARTS STABILITY TO BUILDINGS

Stability of buildings results from a law the converse of the two foregoing, namely that the walls should be built up all equally in equal

[1] MS. *abarbanati.*

stages, which should embrace the whole circuit of the building and the total thickness of the walls no matter of what kind; and although the thin wall dries more rapidly than a thick one it will not have to break as the result of the weight which it may acquire from one day to another; for if a double quantity of it were to dry in one day, a wall of double the thickness would dry in two days or thereabouts, and so a slight difference in weight would be balanced by a slight difference of time.

OF THE POSITION OF FOUNDATIONS AND IN WHAT PLACES THEY ARE A CAUSE OF DESTRUCTION

When the crack in a wall is wider at the top than at the bottom it is a clear sign that the source of the destruction of the wall lies outside the perpendicular of the crack. B.M. 157 v.

OF THE CAUSE OF THE COLLAPSE OF PUBLIC AND PRIVATE BUILDINGS

Walls collapse as a result of cracks which are either vertical or slanting. Cracks which proceed vertically are caused by new walls being built in conjunction with old walls either vertically or with toothings fitted into the old walls; for as these toothings cannot offer any resistance to the insupportable weight of the wall joined on to them they must needs break and allow the new wall to settle down, in which process it will sink a braccio in every ten, or more or less according to the greater or smaller quantity of mortar used for the stones in the construction, and whether the mortar is very liquid or not. And remember always to build the walls first and then add the facing stones, because unless this is done, since the subsidence of the wall in settling will be greater than that of the outer shell, the toothings set in the sides of the wall will necessarily be broken, because the stones used for facing the walls being larger than the stones used in their construction will of necessity take a less quantity of mortar in their joints, and therefore the subsidence will be less. But this cannot happen if the facing of the wall is added after the wall has had time to dry. B.M. 158 r.

TRANSPORTATION OF HOUSES

[*With diagrams*]

Let the houses be transported and arranged in order, and this can be done with ease because these houses are first made in parts upon the open places, and are then fitted together with their timbers on the spot where they are to remain.

Let fountains be made in each piazza.

Let the countryfolk dwell in parts of the new houses when the court is not there. B.M. 270 v.

[*Drawing*]

Cover of the preaching place of the castle. Forster II 70 v.

That angle will have the greatest power of resistance which is most acute, and the most obtuse will be the weakest. Forster II 87 v.

FOUNDATION

[*With drawing*]

Here it is shown how the arches made in the sides of the octagon push the columns of the angles outwards, as is shown in the line *h c* and in the line *t d*, which push the column *m* outwards, that is they exert pressure to drive it from the centre of this octagon. Forster II 93 r.

[*Sketch*]

That part of the bulk of the lower support will be more weighed down upon which is nearer the centre of the weight supported by it. Forster III 13 v.

[*Sketch*]

That in the canals nothing be thrown, and that these canals go straight to the houses. Forster III 23 v.

The hall of the court is one hundred and twenty-eight steps long and its breadth is twenty-seven braccia. Forster III 49 v.

[*Sketch*]

The height of the walls of the courtyard should be half its length, that is if the courtyard be forty braccia the house ought to be twenty high in the walls of the said courtyard, and this courtyard should be half the width of the whole front. Windsor: Drawings 12585 v.

[*Water-stair in the Sforzesca*]

When the descent from the floodgates has been so hollowed out that at the end of its drop it is below the bed of the river, the waters which descend from them will never form a cavity at the foot of the bank, and will not carry away soil in their rebound, and so they will not proceed to form a fresh obstacle but will follow the transverse course along the length of the base of the floodgate from the under side. Moreover if the lowest part of the bank which lies diagonally across the course of the waters be constructed in deep broad steps after the manner of a staircase, the waters which as they descend in their course are accustomed to fall perpendicularly from the beginning of this lowest stage, and dig out the foundations of the bank, will not be able any longer to descend with a blow of irresistible force.

And I give as an example of this the stair down which the water falls from the meadows of the Sforzesca at Vigevano, for the running water falls down it for a height of fifty braccia. Leic. 21 r.

[*With drawing*]

Stairs of Vigevano, below the Sforzesca, with one hundred and thirty steps a quarter of a braccio high and half a braccio wide, down which the water falls without wearing away anything as it finishes its fall; and by these stairs so much soil has come down as to have dried up a swamp, that is by having filled it up; and it has formed meadows from swamps of great depth. Leic. 32 r.

XXXIX

Music

'Music which is consumed in the very act of its birth.' (TRATTATO I 29)

MUSIC has two ills, the one mortal the other wasting; the mortal is ever allied with the instant which follows that of the music's utterance, the wasting lies in its repetition, making it seem contemptible and mean.

C.A. 382 v. a

[*With drawing*]

This is the manner of movement of the bow of the viol-player; and if you make the notches of the wheel in two different sizes[?] (*tempi*), so that one set of teeth are less than the other and they do not meet together as is seen in *a b*, the bow will have an equal movement, otherwise it will go in jerks. But if you make it in the way I say the pinion will always move equally.

B 50 v.

[*Drawing*]

Here you make a wheel with pipes that serve as clappers for a musical round called a Canon, which is sung in four parts, each singer singing the whole round. And therefore I make here a wheel with four cogs so that each cog may take the part of a singer.

B.M. 137 v.

I have several cords drawn in octaves the one above the others, and I wish that each may be drawn a finger more than before. I ask what weight will that be which will draw it, being of equal size or of double size, and what sound will remain.

Forster II 35 v.

Of the music of water falling into its vessel.

Leic. 27 r.

With the help of the mill I will make unending sounds from all sorts of instruments, which will sound for so long as the mill shall continue to move.

C.A. 271 v. a

XL

Tales

'I will create a fiction which shall express great things.'

A CERTAIN man gave up associating with one of his friends because the latter had a habit of talking maliciously against all his friends. This friend whom he had left was once reproaching him, and after many complaints besought him to tell him the reason that had caused him to lose the recollection of so great a friendship as theirs; to which he made reply: I am not willing to be seen in your company any more because I like you, and I do not wish that by talking maliciously to others of me who am your friend, you may cause them to form a bad impression of you, as I have, through your talking maliciously to them of me who am your friend. Consequently as we have no more to do with each other it will appear that we have become enemies, and the fact that you talk of me maliciously, as is your habit, will not be so much worthy of rebuke as if we were constantly in each other's company.

C.A. 306 v. b

Dear Benedetto,—To give you the news of the things here from the east, you must know that in the month of June there appeared a giant who came from the Libyan desert. This giant was born on Mount Atlas, and was black, and he fought against Artaxerxes with the Egyptians and Arabs, the Medes and Persians; he lived in the sea upon the whales, the great leviathans and the ships. When the savage giant fell by reason of the ground being covered over with blood and mire, it seemed as though a mountain had fallen; whereat the country [shook] as though there were an earthquake, with terror to Pluto in Hell, and Mars fearing for his life fled for refuge under the side of Jove.[1]

[1] MS., *Marte temēdo dela vita sera fugito sotto lato dj giove.* These words in Leonardo's writing occur at the side and are not found in the transcript of the Italian edition. I have ventured to insert them where they seemed to fit the sense best, and also to change the order of some of the sentences which are written in the margin.

And from the violence of the shock he lay prostrate on the level ground as though stunned; until suddenly the people believing that he had been killed by some thunderbolt, began to turn about his great beard; and like a flock of ants that range about hither and thither furiously among the brambles beaten down by the axe of the sturdy peasant, so these are hurrying about over his huge limbs and piercing them with frequent wounds.

At this the giant being roused and, perceiving himself to be almost covered by the crowd, suddenly on feeling himself smarting from their stabs, uttered a roar which seemed as though it were a terrific peal of thunder, and set his hands on the ground and lifted up his awe-inspiring countenance; and then placing one of his hands upon his head, he perceived it to be covered with men sticking to the hairs after the fashion of tiny creatures which are sometimes harboured there, and who, as they clung to the hairs and strove to hide among them, were like sailors in a storm who mount the rigging in order to lower the sail and lessen the force of the wind; and at this point he shook his head and sent the men flying through the air after the manner of hail when it is driven by the fury of the winds, and many of these men were found to be killed by those who fell on them like a tempest. Then he stood erect, trampling upon them with his feet.

C.A. 311 r. a

Note.—This and the two pieces that follow seem parts of a fantastic tale written in the form of letters.

The black visage at first sight is most horrible and terrifying to look upon, especially the swollen and bloodshot eyes set beneath the awful lowering eyebrows which cause the sky to be overcast and the earth to tremble.

And believe me there is no man so brave but that, when the fiery eyes were turned upon him, he would willingly have put on wings in order to escape, for the face of infernal Lucifer would seem angelic by contrast with this.

The nose was turned up in a snout with wide nostrils and sticking out of these were quantities of large bristles, beneath which was the arched mouth, with the thick lips, at whose extremities were hairs like those of cats, and the teeth were yellow; and from the top of his instep he towered above the heads of men on horseback.

And as his cramped position had been irksome, and in order to rid himself of the importunity of the throng, his rage turned to frenzy, and he began to let his feet give vent to the frenzy which possessed his mighty limbs, and entering in among the crowd he began by his kicks to toss men up in the air, so that they fell down again upon the rest, as though there had been a thick storm of hail, and many were those who in dying dealt out death. And this barbarity continued until such time as the dust stirred up by his great feet, rising up in the air, compelled his infernal fury to abate, while we continued our flight.

Alas, how many attacks were made upon this raging fiend to whom every onslaught was as nothing. O wretched folk, for you there avail not the impregnable fortresses, nor the lofty walls of your cities, nor the being together in great numbers, nor your houses or palaces! There remained not any place unless it were the tiny holes and subterranean caverns where after the manner of crabs and crickets and creatures like these you might find safety and a means of escape. Oh, how many wretched mothers and fathers were deprived of their children! How many unhappy women were deprived of their companions! In truth, my dear Benedetto, I do not believe that ever since the world was created there has been witnessed such lamentation and wailing of people, accompaned by so great terror. In truth, the human species in such a plight has need to envy every other race of creatures; for though the eagle has strength sufficient to subdue the other birds, they yet remain unconquered through the rapidity of their flight, and so the swallows through their speed escape becoming the prey of the falcon, and the dolphins also by their swift flight escape becoming the prey of the whales and of the mighty leviathans; but for us wretched mortals there avails not any flight, since this monster when advancing slowly far exceeds the speed of the swiftest courser.

I know not what to say or do, for everywhere I seem to find myself swimming with bent head within the mighty throat and remaining indistinguishable in death, buried within the huge belly.

C.A. 96 v. b

[*A fantasy* (*in Brobdingnag*)]

He was blacker than a hornet: his eyes were as red as a burning fire and he rode on a big stallion six spans across and more than twenty long; with six giants tied to his saddle bow and one in his hand which he gnawed with his teeth; and behind him came boars with tusks sticking out of their mouths, perhaps ten spans. I 139 [91] r.

The gentle friar was charmed and delighted: he has already obliged the philosophers to search for our cause in order to feed the intellect. M 80 v.

A workman who was in the habit of often going to wait upon a certain lord without having any petition to make to him, was asked by the lord what his purpose was in coming; he replied that he went there to have one of the pleasures that he could not have, for it gave him pleasure to look at people who were grander than himself, as is the way with common folk, whereas the lord could only look at people who were of less account than himself, and consequently lords were cut off from this pleasure. Forster III 34 v.

XLI

Jests

'You should often amuse yourself when you take a walk for recreation, in watching and taking note of the attitudes and actions of men as they talk and dispute, or laugh or come to blows one with another, both their actions and those of the bystanders who either intervene or stand looking on at these things.'

A JEST

A PRIEST while going the round of his parish on the Saturday before Easter in order to sprinkle the houses with holy water as was his custom, coming to the studio of a painter, and there beginning to sprinkle the water upon some of his pictures, the painter turning round with some annoyance asked him why he sprinkled his pictures in this manner. The priest replied that it was the custom and that it was his duty to act thus, that he was doing a good deed and that whoever did a good deed might expect a recompense as great or even greater; for so God had promised that for every good deed which we do on the earth we shall be rewarded a hundredfold from on high. Then the painter, having waited until the priest had made his exit, stepped to the window above and threw a large bucket of water down on to his back, calling out to him:—'See there is the reward that comes to you a hundredfold from on high as you said it would, on account of the good deed you did me with your holy water with which you have half ruined my pictures'. C.A. 119 r. a

The Franciscan friars at certain seasons have periods of fasting, during which no meat is eaten in their monasteries, but if they are on a journey, as they are then living on almsgiving, they are allowed to eat whatever is set before them. Now a couple of these friars travelling under these conditions chanced to alight at an inn at the same time as a certain merchant and sat down at the same table, and on account of the poverty of the inn nothing was served there except one roasted cockerel. At this the merchant as he saw that it would be scant fare for himself turned to the friars and said:—'On days like these if I remember rightly you are not permitted in your monasteries to eat any kind of meat.' The friars on hearing these words were constrained by their rule to admit without any attempt at argument that this was indeed the case: so the merchant had his desire and devoured the chicken, and the friars fared as best they could.

Now after having dined in this wise all three table-companions set out on their journey together, and having gone a certain distance they came to a river of considerable breadth and depth, and as they were all three on foot, the friars by reason of their poverty and the other from niggardliness, it was necessary according to the custom of the country that one of the friars who had no shoes and stockings should carry the merchant on his shoulders; and consequently the friar having given him his clogs to hold took the man on his back. But as it so happened the friar when he found himself in the middle of the stream bethought himself of another of his rules, and coming to a standstill after the manner of St. Christopher raised his head towards him who was weighing heavily upon him and said:—'Just tell me, have you any money about you?' 'Why you know quite well that I have,' replied the other. 'How do you suppose a merchant like me could travel about otherwise?' 'Alas!' said the friar, 'our rule forbids us to carry any money on our backs'; and he instantly threw him into the water.

As the merchant was conscious that this was done as a jest and out of revenge for the injury he had done them he smiled pleasantly and pacifically, and blushing considerably from shame he endured their revenge. C.A. 150 v. b

If Petrarch loved the laurel so much it was because it is good with sausages and thrushes; I don't attach any value to their trifles.

Tr. 1 a

Frati santi spells Pharisees.[1] Tr. 63 a

[1] MS. *farisei.*

A WORD SAID BY A YOUNG MAN TO AN OLD ONE

On an old man openly reviling a young one and boldly proclaiming that he had no fear of him, the young one made answer that his advanced age served him better as a protection than either his tongue or his strength. Tr. 71 a

JEST

Why the Hungarians keep the double cross. H 62 [14] v.

A man wishing to prove on the authority of Pythagoras that he had been in the world on a former occasion, and another not allowing him to conclude his argument, the first man said to the second:—'And this is a token that I was here on a former occasion, I remember that you were a miller.' The other who felt provoked by his words agreed that it was true, for he also remembered as a token that the speaker had been the ass which had carried the flour for him.

A painter was asked why he had made his children so ugly, when his figures which were dead things he had made so beautiful. His reply was that he made his pictures by day and his children at night. M 58 v.

A sick man who was at the point of death heard someone knocking at the door, and on his asking one of his servants who it was who was knocking at the door, this servant made answer that it was someone who called herself Madame Bona.

Whereat the sick man raised his arms to heaven and praised God with a loud voice, and then told the servants to let her in immediately in order that he might see a good woman before he died, because in all his life he had never seen one. Forster II 30 v.

It was said to someone that he should rise from his bed because the sun had already risen; to which he made answer:—'If I had to make as long a journey and to do as much as he I too should have already risen; but as I have such a short way to go I do not wish to get up yet awhile.' Forster II 31 r.

XLII

Fables

'The mirror bears itself proudly, holding the queen mirrored within it, and after she has departed the mirror remains abject.'

THE privet on feeling its tender branches, laden with new fruit, pricked by the sharp claws and beak of the troublesome blackbird, complained to her with pitiful reproaches, beseeching her that even if she plucked off her delicious fruit she would at any rate not deprive her of her leaves which protected her from the scorching rays of the sun, nor with her sharp claws rend away and strip bare her tender bark.

But to this the blackbird replied with insolent rebuke:—'Silence! rude bramble! Know you not that Nature has made you to produce these fruits for my sustenance? Cannot you see that you came into the world in order to supply me with this very food? Know you not, vile thing that you are, that next winter you will serve as sustenance and food for the fire?' To which words the tree listened patiently and not without tears.

But a short time afterwards the blackbird was caught in a net, and some boughs were cut to make a cage in order to imprison her, and among the rest were some cut from the tender privet to serve for the rods of the cage; and these on perceiving that they would be the cause of the blackbird being deprived of liberty rejoiced and uttered these words:—'We are here, O blackbird, not yet consumed by the fire as you said; we shall see you in prison before you see us burnt.'

The laurel and the myrtle, on seeing the pear-tree being cut down, cried out with a loud voice:—'O pear-tree, where are you going? Where is the pride that you had when you were laden with ripe fruit? Now you will no longer make shade for us with your thick foliage.' Then the pear-tree replied:—'I am going with the husbandman who is cutting me down and who will take me to the workshop of a good sculptor, who by his art will cause me to assume the form of the god Jove, and I shall be dedicated in a temple and worshipped by men in place of Jove. While you are obliged to remain always maimed and stripped of your branches which men shall set around me in order to do me honour.'

The chestnut seeing a man upon the fig-tree bending its branches down towards himself and picking off their ripe fruit and putting it in his mouth, tearing it asunder and crushing it with his hard teeth, shook its boughs and said in a mournful whisper:—'O fig-tree, how much less favoured by Nature are you than I. Look how with me my sweet children all are arranged in close order, clothed first with a fine jacket over which is set the hard rough husk; and not content with conferring such benefits on me she has given them a strong dwelling, and set about it sharp close prickles so that the hands of man may not be able to harm me.' At this the fig-tree and her children began to laugh, and when they had finished laughing she said:—'Know that man is of such a disposition that, as you have found, by means of rods and stones and sticks thrown into your branches he will deprive you of your fruit, and after it has fallen will crush it with his feet or with stones, in such a way that your offspring will issue forth from their armoured house crushed and bruised. But I am touched carefully by his hands and not as you are with sticks and stones.'

The idle fluttering moth, not contented with its power to fly wherever it pleased through the air, enthralled by the seductive flame of the candle, resolved to fly into it, and its joyous movement was the occasion of instant mourning. For in the said flame its delicate wings were consumed, and the wretched moth having fallen down at the foot of the candlestick, all burnt, after much weeping and contrition, wiped the tears from its streaming eyes, and lifting up its face exclaimed:—'O false light, how many are there like me who have been miserably deceived by you in times past! Alas! If my one desire was to behold the light, ought I not to have distinguished the sun from the false glimmer of filthy tallow?'

A nut which found itself carried by a crow to the top of a lofty campanile, having there fallen into a crevice and so escaped its deadly beak, besought the wall by that grace which God had bestowed upon it in causing it to be so exalted and great, and so rich in having bells of such beauty and of such mellow tone, that it would deign to give it succour; that insomuch as it had not been able to drop beneath its old father's green branches and lie in the fallow earth covered by his fallen leaves the wall would not abandon it, for when it found itself in the fierce crow's cruel beak it had vowed that if it escaped thence it would end its days in a small hole. At these words the wall, moved with compassion, was content to give it shelter in the spot where it had fallen. And within a short space of time the nut began to burst open and to put its roots in among the crevices of the stones, and push them farther apart and throw up shoots out of its hollow, and these soon rose above the top of the building; and as the twisted roots grew thicker they commenced to tear asunder the walls and force the ancient stones out of their old positions. Then the wall too late and in vain deplored the cause of its destruction, and in a short time it was torn asunder and a great part fell in ruin.

The ape on finding a nest of small birds approached them with great joy, but as they were already able to fly he could only catch the smallest. Filled with joy he went with it in his hand to his hiding place; and having commenced to look at the tiny bird he began to kiss it; and in his uncontrollable affection he gave it so many kisses and turned it over and squeezed it, until he took away its life. This is said for those who by being too fond of[1] their children bring misfortune upon them.

C.A. 67 r. a

The unhappy willow, on finding herself unable to enjoy the pleasure of seeing her slender boughs attain to such a height as she desired, or even point towards the sky, because she was continually being maimed and lopped and spoiled for the sake of the vine or any other tree which happened to be near, summoned up all her faculties and by this means opened wide the portals of her imagination, remaining in continual meditation, and seeking in the world of plants for one wherewith to ally herself which could not need the help of her branches. So continuing for a time with her imagination at work, the thought of the gourd suddenly presented itself to her mind, and all her branches quivered in her intense joy, for it seemed to her that she had found the

[1] MS. *per non gastigare.*

right companion for the purpose she desired, because the gourd is by nature more fitted to bind others than to be bound herself. After coming to this conclusion she lifted up her branches towards the sky and waited, on the look out for some friendly bird to serve as the intermediary of her desire. Among the rest she descried the magpie near to her and said to him:—'O gentle bird, by the refuge you have lately found among my branches at dawn, when the hungry, cruel, and rapacious falcon has wished to devour you,—by that rest you have often found in me when your wings craved rest,—by those delights you have enjoyed among my branches in amorous dalliance with your companions,—I entreat you to go and seek out the gourd and obtain from her some of her seeds, telling her that I will care for whatever is born from them as though they were my own offspring, and in like manner use all such words as may incline her to the like purpose, though to you who are a master of language there is no need for me to give instruction. If you will do this I am content to let your nest be in the fork of my boughs together with all your family without payment of any rent.' So the magpie, after stipulating with the willow for certain further conditions, the most important being that she should never admit upon her boughs any snake or polecat, cocked his tail and lowered his head, and casting himself loose from the bough let himself float on his wings; and beating about with these in the fleeting air, seeking hither and thither, and guiding himself by using his tail as a rudder, he came to a gourd, and after courteously saluting her obtained by a few polite word the seeds for which he sought. On taking these back to the willow he was welcomed with joyful looks; and then scraping away with his foot some of the earth near the willow he planted the grains with his beak round about her in a circle.

These soon began to grow, and as the branches increased and opened out they began to cover all the branches of the willow, and their great leaves shut away from it the beauty of the sun and the sky. And all this evil not sufficing, the gourds next began to drag down to the ground in their rude grip the tops of the slender boughs, twisting them and distorting them in strange shapes. Then the willow after shaking and tossing herself to no purpose to make the gourds loose their hold, and vainly for days cherishing such idle hopes, since the grasp of the gourds was so sure and firm as to forbid such thoughts, seeing the wind pass by, forthwith commended herself to it. And the wind blew hard; and it rent open the willow's old and hollow trunk, tearing it in two parts right down to its roots; and as they fell asunder she vainly bewailed her fate, confessing herself born to no good end.

Some flames had already lived for a month in a glass-furnace when they saw a candle approaching in a beautiful and glittering candlestick. They strove with great longing to reach it; and one of their number left its natural course and wound itself into an unburnt brand upon which it fed, and then passed out at the other end by a small cleft to the candle which was near, and flung itself upon it, and devouring it with the utmost voracity and greed consumed it almost entirely; then desirous of prolonging its own life, it strove in vain to return to the furnace which it had left, but was forced to droop and die together with the candle. So at last in lamentation and regret it was changed to foul smoke, leaving all its sisters in glowing and abiding life and beauty.

Wine, the divine liquor of the grape, finding itself in a golden richly chased cup upon Mahomet's table, after being transported with pride at such an honour, was suddenly assailed by a contrary feeling, and said to itself:—'What am I doing? What is it that I am rejoicing at? Cannot I see that I am near to my death, in that I am about to leave my golden dwelling in this cup and enter into the foul and fetid caverns of the human body, to be there transformed from a sweet fragrant nectar to a foul and disgusting fluid? And such an evil not sufficing, I must needs lie for a long time in foul receptacles with other noisome and putrid matter evacuated from the human intestines.' It cried to heaven demanding vengeance for such injury and that an end might be put to such an insult, so that since that part of the country produced the most beautiful and finest grapes in the whole world these at least should not be turned into wine. Then Jove caused the wine which Mahomet drank to rise in spirit up to the brain, and to infect this to such a degree as to make him mad; and he committed so many follies that when he came to his senses he made a decree that no Asiatic should drink wine; and thus the vine and its fruits were left at liberty.

As soon as the wine has entered into the stomach it commences to swell up and boil over; and then the spirit of that man commences to abandon his body, and rising as though towards the sky it reaches the brain, which causes it to become divided from the body; and so it begins to infect him and to cause him to rave like a madman; and so he perpetrates irreparable crimes, killing his own friends.

C.A. 67 r. b

The rat was being besieged in its tiny house by the weasel which with unceasing vigilance was awaiting its destruction, and through a tiny chink it was considering its great danger. Meanwhile the cat came and suddenly seized hold of the weasel and immediately devoured it. Thereupon the rat, profoundly grateful to its deity, having offered up some of its hazel-nuts as a sacrifice to Jove, issued forth from its hole in order to repossess itself of the liberty it had lost, and was instantly deprived of this and of life itself by the cruel claws and teeth of the cat.

C.A. 67 v. a

Fable of the tongue bitten by the teeth.

The cedar, arrogant by reason of its beauty, despising the plants which were round about it, caused them to be all removed from its presence, and then the wind, not meeting with any obstacle, tore it up by the roots and threw it on to the ground.

The ant having found a grain of millet, the grain as it felt itself seized by it cried out:—'If you will do me the great favour of allowing me to fulfil my desire to germinate I will give you of myself a hundred-fold.' And so it was.

The spider, having found a bunch of grapes, which because of its sweetness was much visited by bees and various sorts of flies, fancied that it had found a spot very suitable for its wiles. And after having lowered itself down by its fine thread and entered its new habitation, there day by day, having ensconced itself in the tiny holes made by the spaces between the various grapes in the bunch, like a robber it assaulted the wretched animals which were not on their guard against it. But after some days had passed the keeper of the vineyard cut this bunch off and placed it with the others, and it was pressed with them. And the grapes therefore served as trap and snare for the deceiving spider as well as for the flies whom he had deceived.

The traveller's joy, not remaining contented in its hedge, commenced to pass across the high road with its branches and to attach itself to the opposite hedge; whereupon it was broken by the passers-by.

The ass having fallen asleep upon the ice of a deep lake, the heat of its body caused the ice to melt, and the ass being under water awoke to his great discomfort, and was speedily drowned.

A certain patch of snow, finding itself clinging to the top of a rock which was perched on the extreme summit of a very high mountain, being left to its own imagination began to reflect and to say within itself:—'Shall I not be thought haughty and proud for having placed myself in so exalted a spot, being indeed a mere morsel of snow? And for allowing that such a vast quantity of snow as I see around me should take a lower place than mine? Truly my small dimensions do not deserve this eminence; and in proof of my insignificance I may readily acquaint myself with the fate which but yesterday befell my companions, who in a few hours were destroyed by the sun; and this came about from their having placed themselves in a loftier station than was required of them. I will flee from the wrath of the sun, and abase myself, and find a place that befits my modest size.'

Then throwing itself down, it began to descend, rolling down from the lofty crags on to the other snow; and the more it sought a lowly place, the more it increased in bulk, until at last ending its course upon a hill, it found itself almost the equal in size of the hill on which it rested, and it was the last of the snow which was melted that summer by the sun.

This is said for those who by humbling themselves are exalted.

The hawk, being unable to endure with patience the way in which the duck was hidden from him when she fled before him and dived beneath the water, desired also to follow in pursuit beneath the water; and getting its wings wetted it remained in the water; and the duck raised herself in the air and mocked at the hawk as it drowned.

The spider, wishing to capture the fly in its secret web, was cruelly slain above it by the hornet.

The eagle, wishing to mock at the owl, got its wings smeared with bird-lime and was captured by man and killed. C.A. 67 v. b

THE CEDAR

The cedar, having conceived the desire of bearing on its summit a large and beautiful fruit, set itself to carry it into effect with all the powers of its sap; which fruit after it had grown was the cause of making the tall and slender summit bend down.

THE PEACH-TREE

The peach-tree, being envious of the great quantity of fruit that it saw its neighbour the nut-tree bearing, decided to do the same, and loaded itself with its fruit to such an extent that the weight of this fruit threw it down, uprooted and broken, level with the ground.

THE NUT-TREE

The nut-tree, displaying to the passers-by upon the road the richness of its fruit, every man stoned it.

When the fig-tree stood without fruit no one looked at it. Wishing by producing this fruit to be praised by men, it was bent and broken by them.

The fig-tree, standing near to the elm, and perceiving that her boughs bore no fruit themselves, yet had the hardihood to keep away the sun from her own, unripe figs, rebuked her, saying:—'O Elm, are you not ashamed to stand in front of me? Only wait until my children are fully grown and you will see where you will find yourself.' But when her offspring were ripe a regiment of soldiers came to the place, and they tore off the branches of the fig-tree in order to take her figs, and left her all stripped and broken.

And as she thus stood maimed in all her limbs the elm questioned her saying:—'O Fig tree, how much better was it to be without children than to be brought by them to so wretched a pass?' C.A. 76 r. a

The fire rejoicing in the dried wood which it had found in the fire-place, and having taken hold of it, perceiving itself to have grown enormously above the wood and to have made itself of considerable size, commenced to exalt its gentle and tranquil soul in puffed-up and insupportable pride, making itself almost believe that it had drawn the whole of the superior element down into the few logs. And commencing to fume and fill all the fireplace round about it with explosions and showers of sparks, already the flames which had become big were all in conjunction making their way towards the air; then the highest flames striking upon the bottom of the saucepan above . . .

A vestige of fire which had remained in a small lump of charcoal among the warm embers, was very scantily and poorly nourished by the small quantity of nutriment that was left there. When the superintendent of the kitchen arrived there in order to perform her usual work of preparing the food, having placed the logs on the hearth, and having succeeded by means of a sulphur-match in getting a small flame from the charcoal though it was almost extinct, she set it among the logs which she had arranged and took a saucepan and set it over it and without any misgivings went away from it.

Then the fire, after rejoicing at the dried logs placed upon it, began to ascend and drive out the air from the spaces between the logs, twining itself in among them in sportive and joyous progress, and having commenced to blow through the spaces between the logs out of which it had made delightful windows for itself, and to emit gleaming and shining flames, it suddenly dispels the murky darkness of the closed-in kitchen, and the flames having already increased began to play joyfully with the air that surrounded them, and singing with gentle murmur they created a sweet sound. C.A. 116 v. b

The thrushes rejoiced greatly on seeing a man catch the owl and take away her liberty by binding her feet with strong bonds. But then by means of bird-lime the owl was the cause of the thrushes losing not only their liberty but even their life. This is said of those states which rejoice at seeing their rulers lose their liberty, in consequence of which they afterwards lose hope of succour and remain bound in the power of their enemy, losing their liberty and often life. C.A. 117 r. b

While the dog was asleep on the coat of a sheep, one of its fleas, becoming aware of the smell of the greasy wool, decided that this must be a place where the living was better and more safe from the teeth and nails of the dog than getting his food on the dog as he did. Without more reflection therefore it left the dog and entering into the thick wool began with great toil to try to pass to the roots of the hairs; which enterprise however after much sweat it found to be impossible, owing to these hairs being so thick as almost to touch each other, and there being no space there where the flea could taste the skin. Consequently after long labour and fatigue it began to wish to go back to its dog which however had already departed, so that after long repentance and bitter tears it was obliged to die of hunger. C.A. 119 r. a

Once upon a time the razor emerging from the handle which served it as a sheath, and placing itself in the sun, saw the sun reflected on its surface, at which thing it took great pride, and turning it over in its thoughts it began to say to itself:—'Am I to go back any more to that shop from which I have just now come away? No surely! It cannot be the pleasure of the gods that such radiant beauty should stoop to such vile uses! What madness would that be which should induce me to scrape the lathered chins of rustic peasants and to do such menial service? Is this body made for actions such as these? Certainly not! I will go and hide myself in some retired spot, and there pass my life in tranquil ease.'

And so having hidden itself away for some months, returning one day to the light and coming out of its sheath it perceived that it had acquired the appearance of a rusty saw, and that its surface no longer reflected the sun's radiance. In vain with useless repentance it bemoaned its irreparable hurt, saying to itself:—'Ah how much better would it have been to have let the barber use that lost edge of mine that had so rare a keenness! Where now is the glittering surface? In truth the foul insidious rust has consumed it away!'

The same thing happens with minds which in lieu of exercise give themselves up to sloth; for these like the razor lose their keen edge, and the rust of ignorance destroys their form.

A stone of considerable size, only recently left uncovered by the waters, stood in a certain spot perched up at the edge of a delightful copse, above a stony road, surrounded by plants bright with various flowers of different colours, and looked upon the great mass of stones which lay heaped together in the road beneath. And she became filled with longing to let herself down there, saying within herself:—'What am I doing here with these plants? I would fain dwell in the company of my sisters yonder'; and so letting herself fall she ended her rapid course among her desired companions. But when she had been there for a short time she found herself in continual distress from the wheels of the carts, the iron hoofs of the horses and the feet of the passers-by. One rolled her over, another trampled upon her; and at times she raised herself up a little as she lay covered with mud or the dung of some animal, and vainly looked up at the place from whence she had departed as a place of solitude and quiet peace.

So it happens to those who, leaving a life of solitude and contemplation, choose to come and dwell in cities among people full of infinite wickedness. C.A. 175 v. a

As the painted butterfly was idly wandering and flitting about through the darkened air a light came within sight, and thither immediately it directed its course, and flew round about it in varying circles marvelling greatly at such radiant beauty. And not contented merely to behold, it began to treat it as was its custom with the fragrant flowers, and directing its flight it approached with bold resolve close to the light, which thereupon consumed the tips of its wings and legs and the other extremities; and then dropping down at the foot of it, it began to consider with astonishment how this accident had been brought about; for it could not so much as entertain a thought that any evil or hurt could possibly come to it from a thing so beautiful; and then having in part regained the strength which it had lost, it took another flight and passed right through the body of the flame, and in an instant fell down burned into the oil which fed the flame, preserving only so much life as sufficed it to reflect upon the cause of its destruction, saying to it:—'O accursed light! I thought that in you I had found my happiness! Vainly do I lament my mad desire, and by my ruin I have come to know your rapacious and destructive nature.'

To which the light replied:—'Thus do I treat whoever does not know how to use me aright.'

This is said for those who when they see before them these carnal and worldly delights, hasten towards them like the butterfly, without ever taking thought as to their nature, which they know after long usage to their shame and loss.

The flint on being struck by the steel marvelled greatly and said to it in a stern voice:—'What arrogance prompts you to annoy me? Trouble me not, for you have chosen me by mistake; I have never done harm to anyone.' To which the steel made answer:—'If you will be patient you will see what a marvellous result will issue forth from you.'

At these words the flint was pacified and patiently endured its martyrdom, and it saw itself give birth to the marvellous element of fire which by its potency became a factor in innumerable things.

This is said for those who are dismayed at the outset of their studies, and then set out to gain the mastery over themselves and in patience to apply themselves continuously to those studies, from which one sees result things marvellous to relate. C.A. 257 r. b

The lily planted itself down upon the bank of the Ticino, and the stream carried away the bank and with it the lily. H 44 r.

The oyster being thrown out with other fish near to the sea from the house of a fisherman, prayed to a rat to take him to the sea; the rat who was intending to devour him bade him open, but then as he bit him the oyster squeezed his head and held it; and the cat came and killed him. H 51 [3] v.

The pen has necessary companionship with the penknife, and moreover useful companionship for the one without the other is ineffective.

L cover v.

When the crab had placed itself beneath the rock in order to catch the fish that entered underneath it, the wind came with ruinous downfall of the rocks, and these by rolling themselves down destroyed the crab.

The spider had placed itself among the grapes to catch the flies that fed on them. The time of vintage came and the spider was trodden under foot together with the grapes.

The vine that has grown old upon the old tree falls together with the destruction of this tree. It was by reason of its bad company that it failed together with it.

The torrent carried away so much earth and stones in its bed that it was then obliged to change its position.

The net which was accustomed to catch fish was destroyed and carried away by the fury of the fish.

The ball of snow the more it rolled as it descended from the mountains of the snow was continually more and more increasing its size.

The willow which by reason of its long shoots and by growing so as to surpass every other plant had become the companion of the vine which is pruned every year, was also itself always mutilated.

B.M. 42 V.

The water on finding itself in the proud sea, its element, was seized with a desire to rise above the air; and aided by the element of fire having mounted up in thin vapour, it seemed almost as thin as the air itself; and after it had risen to a great height it came to where the air was more rarefied and colder, and there it was abandoned by the fire; and the small particles being pressed together were united and became heavy; and dropping from thence its pride was put to rout, and it fell from the sky, and was then drunk up by the parched earth, where for a long time it lay imprisoned and did penance for its sin.

Forster III 2 r.

The light above the candle is fire in a chain; consuming that it consumes itself.

The wine consumed by the drunkard, this wine revenges itself upon the drinker. Forster III 21 r.

The ink is arraigned for its blackness by the whiteness of the paper, which sees itself soiled by it.

The paper on seeing itself all spotted by the murky blackness of the ink grieves over it; and this ink shows it that by the words which it composes upon it it becomes the cause of its preservation.

Forster III 27 r.

The fire, when heating the water placed in the cooking-pot, says to the water that it does not deserve to stand above the fire, the king of the elements; and so it wishes by the violence with which it boils to drive away the water from the cooking-pot; this, therefore, in order to show it honour by obeying it, descends below and drowns the fire.

Forster III 30 r.

The knife, an artificial weapon, deprives man of his nails—his natural weapon.

The mirror bears itself proudly, holding the queen mirrored within it, and after she has departed the mirror remains abject.

Forster III 44 v.

The heavy iron is reduced to such a state of thinness by the file that a breath of wind suffices to carry it away. Forster III 47 r.

The plant complains of the dry and old stick which was placed at its side and of the dry stakes that surround it; the one keeps it upright, the other protects it from bad companions. Forster III 47 v.

XLIII

A Bestiary

'Nature has given such power of understanding to animals that in addition to the perception of what is to their own advantage they know what is to the disadvantage of the enemy.'

LOVE OF VIRTUE

THE lark is a bird of which it is told that if it is taken into the presence of anyone who is ill, then if the sick person is going to die the bird turns away its head and does not look at him. But if the sick person is going to recover, the bird never takes its eyes off him, and is the cause of all his sickness leaving him. Similarly the love of virtue never regards a mean or bad thing, but always rather dwells among things honest and virtuous, and repatriates itself in noble hearts like birds in green forests upon flowery branches. And this love reveals itself more in adversity than in prosperity, acting as does light which shines most where it finds the darkest spot.[1] H 5 r.

ENVY

Of the kite one reads that when it sees that its children in the nest are too fat it pecks their sides out of envy and keeps them without food.

CHEERFULNESS

Cheerfulness is characteristic of the cock, for it rejoices over every little thing and sings with varied and joyous movements.

[1] The allegories about animals in this Manuscript are derived from early bestiaries. The extent of Leonardo's debt to his sources is set forth by Gerolamo Calvi in *Il Manoscritto H di L da V. Il 'Fiore di Virtu' e L'Acerba di Cecco d'Ascoli.* Archivio Storico Lombardo Anno XXV Fasc. XIX 1898.

SADNESS

Sadness may be compared to the raven, which on seeing its newborn children white, departs with great grief and abandons them with sad lamentations, and does not give them any food until it discerns a few black feathers. H 5 v.

PEACE

Of the beaver one reads that when it is pursued, knowing this to be on account of the virtue of its testicles for medicinal uses, not being able to flee any farther it stops, and in order to be at peace with its pursuers bites off its testicles with its sharp teeth and leaves them to its enemies.

ANGER

It is said of the bear that when he goes to the beehives to take the honey from them, the bees commence to sting him, so that he leaves the honey and rushes to avenge himself; and wishing to take vengeance upon all those who are biting him he fails to take vengeance on any, with result that his course becomes changed to frenzy, and in his exasperation he throws himself upon the ground, vainly trying to defend himself with his hands and feet. H 6 r.

GRATITUDE

The virtue of gratitude is said to be found especially in the birds called hoopoes, which being conscious of the benefits they have received from father and mother in life and nourishment, when they see these becoming old make a nest for them and cherish them and feed them, plucking out their old and shabby feathers with their beaks, and by means of certain herbs restoring their sight, so that they return to a state of prosperity.

AVARICE

The toad feeds on earth and always remains lean because it never satisfies itself, so great is its fear lest the supply of earth should fail. H 6 v.

INGRATITUDE

The pigeons serve as a symbol of ingratitude; for when they are of an age no longer to have need of being fed, they commence to fight with their father, and the combat does not end until the young one has driven his father out and taken his wife and made her his own.

CRUELTY

The basilisk is so exceedingly cruel that when it cannot kill animals with the venom of its gaze it turns towards the herbs and plants, and looking fixedly upon them makes them wither up. H 7 r.

MAGNANIMITY

Of the eagle it is said that it never has so great a hunger that it does not leave of its prey to those birds which are round about; and as these are not able to forage for themselves it is necessary that they pay court to the eagle, since by this means they are fed.

CORRECTION

If the wolf while prowling warily round some cattle-stall should chance to set his foot in a trap so that he makes a noise, he bites his foot off in order to punish himself for his mistake. H 7 v.

BLANDISHMENTS

The siren sings so sweetly as to lull the mariners to sleep, and then she climbs upon the ships and kills the sleeping mariners.

PRUDENCE

The ant from its natural sagacity provides in the summer for the winter, killing the seeds after having gathered them, in order that they may not germinate, and then in time it eats them.

MADNESS

As the wild bull hates the colour red the hunters drape in red the trunk of a tree, and the bull charges it furiously and gets his horns fixed in it, and then the huntsmen kill him. H 8 r.

JUSTICE

We may compare the virtue of justice to the king of the bees, who orders and arranges everything on a system, because some bees are ordered to go among the flowers, others are ordered to work, others to fight with the wasps, others to take away the dirt, others to accompany and attend the king. And when he becomes old and has no wings they carry him, and if any one of them fail in his duty he is punished without any forgiveness.

TRUTH

Although partridges steal each other's eggs nevertheless the children born from these eggs always return to their true mother. H 8 v.

FIDELITY OR LOYALTY

The cranes are so faithful and loyal to their king that at night when he is asleep some pace up and down the meadow to keep guard over him from a distance; others stand near at hand, and each holds a stone in his foot, so that if sleep should overcome them the stone would fall and make such a noise that they would be wakened up. There are others who sleep together around the king, and they do this every night taking it in turn so that their king may not come to find them wanting.

DECEIT

The fox when he sees a flock of magpies or jackdaws or birds of this kind, instantly throws himself on the ground with mouth open in such a way as to seem dead: the birds think to peck at his tongue and he bites off their heads. H 9 r.

A LIE

The mole has very small eyes and always remains underground; it lives as long as it stays in concealment, and as soon as ever it comes to the light it instantly dies, because it becomes known—So it is with a lie.

FORTITUDE

The lion never feels fear; on the contrary it fights with a stout heart in fierce combat against the crowd of hunters, always seeking to injure the first who has injured him.

FEAR OR COWARDICE

The hare is always timid, and the leaves that fall from the trees in autumn keep it always in fear and often cause it to flee. H 9 V.

MAGNANIMITY

The falcon only preys on large birds, and it would let itself die before it would feed on the young or eat putrid flesh.

VAINGLORY

As regards this vice we read of the peacock being more subject to it than any other creature, because it is always contemplating the beauty of its tail, spreading it out in the form of a wheel and attracting to itself by its cries the attention of the surrounding animals.

And this is the last vice that can be conquered. H 10 R.

CONSTANCY

For constancy the phoenix serves as a type; for understanding by nature its renewal it is steadfast to endure the burning flames which consume it, and then it is reborn anew.

INCONSTANCY

The swift is put for inconstancy, for it is always in movement, since it cannot endure the slightest discomfort.

TEMPERANCE

The camel is the most lustful animal that there is, and it will follow the female a thousand miles, but if it lived continually with its mother or sister it would never touch them, so well does it know how to control itself. H 10 v.

INTEMPERANCE

The unicorn through its lack of temperance, and because it does not know how to control itself for the delight that it has for young maidens, forgets its ferocity and wildness; and laying aside all fear it goes up to the seated maiden and goes to sleep in her lap, and in this way the hunters take it.

HUMILITY

Of humility one sees the supreme instance in the lamb, which submits itself to every animal. And when they are given as food to lions in captivity they submit themselves to them as to their own mothers, in such a way that it has often been seen that the lions are unwilling to kill them. H 11 r.

PRIDE

The falcon from its haughtiness and pride thinks to overcome and lord it over all the other birds of prey, because it wishes to reign alone: and many times the falcon has been seen to attack the eagle the queen of birds.

ABSTINENCE

The wild ass if when going to the spring to drink it should find the water muddy, has never so great a thirst as to cause it not to abstain from drinking and wait until the water grows clear.

GLUTTONY

The vulture is so given up to gluttony that it would go a thousand miles in order to feed on carrion, and this is why it follows armies. H 11 v.

CHASTITY

The turtle-dove never wrongs its mate; and if the one dies the other observes perpetual chastity, and never rests upon a green branch or drinks of clear water.

LEWDNESS

The bat by reason of its unbridled lewdness does not follow any natural law in pairing, but male goes with male, female with female, as they chance to find themselves together.

MODERATION

The ermine because of its moderation eats only once a day, and it allows itself to be captured by the hunters rather than take refuge in a muddy lair, in order not to stain its purity. H 12 r.

THE EAGLE

The eagle when it is old flies so high that it scorches its feathers; and nature consents that it renews its youth by falling into shallow water.

And if its young ones cannot bear to gaze at the sun it does not feed them. No bird that does not wish to die should approach its nest. The animals go much in fear of it but it does not harm them. It always leaves them a portion of its prey.

THE *LUMERPA*. FAME

This is born in Asia Magna and shines so brightly that it absorbs its shadows. And in dying it does not lose this light, and the feathers never fall out. And the feather which is detached ceases to shine.

H 12 V.

THE PELICAN

This bears a great love to its young; and if it finds them slain in the nest by a serpent it pierces itself to the heart in their presence, and by bathing them with a shower of blood it restores them to life.

THE SALAMANDER

The salamander in the fire refines its rough skin.—For virtue.

It has no digestive organs and does not seek any other nourishment than fire, and often in this it renews its rough skin.

THE CHAMELEON

This lives on air and it is there at the mercy of all the birds. And in order to be safer it flies above the clouds, and there finds an air that is so rarefied as to be incapable of supporting any bird that would follow it.

At this height there flies nothing save that to whom it is given by the heavens: it is there that the chameleon flies. H 13 r.

ALEPO. FISH

The *alepo* cannot live out of water.

OSTRICH

For armies, food of commanders.

It extracts nourishment from iron; hatches eggs by its gaze.

SWAN

The swan is white without any spot, and sings sweetly as it dies; this song ends its life.

STORK

It cures itself of sickness by drinking salt water. If it finds its companion in fault it abandons her. When it is old its young ones brood over it and nourish it until it dies. H 13 v.

GRASSHOPPER

This with its song puts the cuckoo to silence. It dies in oil and is revived in vinegar. It sings through the burning heats.

BAT

For vice which cannot endure where virtue is.

This loses its sight more where the light has more radiance, and becomes more blinded the more it looks at the sun.

PARTRIDGE

This changes from female to male and forgets its former sex. Out of envy it steals the eggs of others and hatches them, but the young ones follow their true mother.

SWALLOW

This by means of celandine opens the eyes of its little ones when blind. H 14 r.

OYSTER—FOR TREASON

This opens completely when the moon is full: and when the crab sees it it throws a piece of stone or a twig into it and thus prevents it from closing up, so that it serves the crab for a meal.

So it may be with the mouth when it tells its secret, that it puts itself at the mercy of the indiscreet listener.

BASILISK—CRUELTY

This is shunned by all the serpents; the weasel fights with it by means of rue and slays it. Rue for virtue.

ASP

This carries sudden death in its fangs; and in order not to hear the enchantments it stops up its ears with its tail. H 14 v.

DRAGON

This twines itself round the legs of the elephant, and it falls upon him and both die. And in dying it has its revenge.

VIPER

This in pairing buries her mouth and at the end clenches her teeth and kills her husband; afterwards the sons having waxed big within her body tear open her belly and slay their mother.

SCORPION

The saliva spat out upon the scorpion when fasting slays it after the manner of abstinence from gluttony, which carries away and puts an end to the illnesses that proceed from this gluttony, and opens the path to the virtues. H 15 r.

CROCODILE—HYPOCRISY

This animal seizes a man and instantly kills him; and after he is dead it mourns for him with a piteous voice and many tears, and having ended its lament it cruelly devours him. It is thus with the hypocrite, whose face is bathed with tears over every slight thing, showing himself thus to have the heart of a tiger; he rejoices in his heart over another's misfortunes with a face bedewed with tears.

TOAD

The toad shuns the light of the sun: if however it be kept in it by force it puffs itself out so much as to hide its head below and deprives itself of its rays. So acts whoever is the enemy of clear and radiant virtue, who cannot maintain itself in its presence save by force, with puffed-up courage. H 17 r.

THE CATERPILLAR—FOR VIRTUE IN GENERAL

The caterpillar which through the care exercised in weaving round itself its new habitation with admirable design and ingenious workmanship, afterwards emerges from it with beautiful painted wings, rising on these towards heaven.

THE SPIDER

The spider brings forth out of herself the delicate and subtle web which gives back to it as its reward the prey that it has taken.

H 17 V.

THE LION

This animal with its resounding roar rouses its cubs on the third day after their birth and teaches them the use of all their dormant senses, and all the wild creatures which are in the forest flee away.

One may liken these to the children of virtue who are wakened by the sound of praise: their studies grow in distinction, raising them continually more and more, and at the sound all that is evil flees away, shunning those who are virtuous.

The lion also covers over his tracks so as to leave nothing to indicate his course to his enemies. So it is well for captains that they should conceal the secrets of their minds, in order that the enemy may have no conception of their plans. H 18 r.

TARANTULA

The bite of the tarantula fixes a man in his purpose, that is in what he was thinking about when he was bitten.

LONG-EARED OWL AND LITTLE OWL

These punish those who have a skirmish with them by depriving them of life; and nature has so ordained in order that they may be fed.

H 18 V.

THE ELEPHANT

The great elephant has by nature qualities which rarely occur among men, namely probity, prudence, and the sense of justice and of religious observance. Consequently when there is a new moon they go to the rivers, and there having solemnly purified themselves they proceed to bathe, and after thus saluting the planet they go back to the woods. And when they are ill they throw themselves upon their backs and toss up plants toward heaven as though they wished to offer sacrifice. They bury their tusks when they drop out from old age. Of these two tusks they use one to dig up roots in order to feed themselves and keep the point of the other sharp in order to fight with it.

When they are conquered by the hunters and overcome by fatigue the elephants clash their tusks, and having thus broken them off use them for their ransom.

They are mild in disposition and are conscious of dangers.

If one of them should come upon a man alone who has lost his way he puts him back peacefully in the path from which he has wandered. If he should come upon the man's footprints before he sees him he fears a snare, and so he stops and blows through his trunk as he shows them to the other elephants; and these then form themselves into a company and advance cautiously.

These animals always proceed in companies. The oldest goes in front and the next oldest remains the last, and thus they enclose the company.

They fear shame and only pair at night and secretly, and do not rejoin the herd after pairing until they have first bathed themselves in the river.

They do not fight over their females as other creatures do.

It is so peaceable that its nature does not allow it willingly to injure creatures less powerful than itself. If it should chance to meet a drove or flock of sheep it puts them aside with its trunk so as to avoid trampling upon them with its feet; and it never injures others unless it is provoked. When one of them has fallen into a pit the others fill the pit with branches, earth and stones, so that they raise the floor in such a way that it may easily make its escape. They have a great dread of the grunting of pigs and retreat hastily before it, causing no less damage with their feet to each other than to their enemies. They delight in rivers and are always wandering about in their vicinity; but on account of their great weight they are unable to swim. They devour stones, and the trunks of trees are their most welcome food. They hate rats. Flies are much attracted by their smell, and as they settle on their backs they wrinkle up their skin, deepening its tight folds, and so kill them.

When they are crossing rivers they send their young towards the fall of the stream, and standing themselves up stream they break the united course of the water so that the current may not carry them away.

The dragon throws itself under the elephant's body, twines its tail round its legs and clings to its ribs with wings and claws and bites open its throat. The elephant falls on top of it and the dragon bursts open; thus it revenges itself by the death of its enemy.

H. 19 r. and v., 20 r. and v.

THE DRAGON

These band themselves together in companies and twine after the manner of roots, cross swamps with their heads raised and swim towards where they find better pasture; and if they did not thus combine they would be drowned.—So the union is made.

H 20 v. and 21 r.

SERPENTS

The serpent, a very large animal, when it sees a bird in the air inhales its breath with such vigour as to draw the birds into its mouth. Marcus Regulus the Consul of the Roman army was with his army attacked by such a monster and almost routed. After the creature had been slain by a catapult it was found to measure a hundred and twenty-five feet, that is sixty-four and a half braccia:[1] its head towered above all the trees in a wood. H 21 r.

THE BOA

This is a great snake which twines itself round the legs of the cow in such a way that it cannot move, and then it sucks it so as almost to dry it up. One of the species was killed on the hill of the Vatican in the time of the Emperor Claudius, and it had a whole boy inside it whom it had swallowed. H 21 r. and v.

THE ELK—CAPTURED WHEN ASLEEP

This beast is a native of the island of Scandinavia. It has the shape of a great horse except for the differences caused by the great length of

[1] It is not always possible to harmonize Leonardo's measurements.

the neck and ears. It crops the grass going backwards, for its upper lip is so long that if it were to feed while going forward it would cover up the grass. It has its legs without any joints and so when it wishes to go to sleep it leans against a tree; and the hunters after having reconnoitred the spot at which it is accustomed to sleep saw the tree almost through, and when afterwards it leans against it as it sleeps it falls in its sleep and so the hunters take it. Every other method of capturing it is bound to fail because it runs with incredible speed.

H 21 V.

BONASUS—IT INJURES AS IT FLIES

This is a native of Paconia, and it has a neck with a mane like a horse: in all other respects it resembles a bull except that its horns bend inwards to such an extent that it cannot butt with them. This is why its only refuge is in flight, in which it voids its excrement a distance of four hundred braccia from its course, and wherever this touches it burns like fire.

LIONS, LEOPARDS, PANTHERS, TIGERS

These keep their claws in sheath and never put them out except when on the back of their prey or an enemy.

LIONESS

When the lioness defends her cubs from the hands of the hunters, in order not to be affrighted by the spears she lowers her eyes to the ground, so that her cubs may not be taken prisoners through her flight.

H 22 r.

LION

This animal which is so terrible fears nothing more than the noise of empty carts and in like manner the crowing of cocks, and when it sees these it is much terrified, gazes at their combs with a look of fear and is strangely perturbed even though its face is covered.

THE PANTHER IN AFRICA

This has the shape of a lioness, but it is taller in the leg and slimmer and longer and quite white, marked with black spots after the manner of rosettes; all the animals are fascinated by these as they gaze at them and they would remain standing there always if it were not for the terror of its face; being conscious of this therefore it hides its face, and the animals that are round about it take courage and draw near so as to be able the better to enjoy so much beauty: it then suddenly seizes on the nearest and instantly devours it. H 22 v. and 23 r.

CAMELS

The Bactrian have two humps, the Arabian one. They are swift in battle and very useful for carrying burdens. This animal is a great observer of rule and proportion, for it does not move at all if its load is larger than it is accustomed to, and if it is taken too long a journey it does the same and stops suddenly, so that the merchants are obliged to make their lodging there. H 23 r.

TIGER

This is a native of Hyrcania; it bears some resemblance to the panther from the various spots on its skin; and it is an animal of terrifying speed. When the hunter finds its cubs he carries them off instantly, after placing mirrors at the spot from which he has taken them, and then immediately takes to flight upon a swift horse.

The panther when it returns finds the mirrors fixed to the ground and in looking at these it thinks that it sees its own children, until by scratching with its paw it discovers the fraud and then following the scent of its cubs it pursues the hunter. And as soon as the hunter sees the tigress he abandons one of the cubs, and this she takes and carries it to her lair and instantly sets off again after the hunter, and this is repeated until he gains his boat. H 23 v. and 24 r.

CATOBLEPAS

It is found in Ethiopia near to the principal source of the Niger. It is an animal which is not very large. It is sluggish in all its limbs and has the head so large that it carries it awkwardly, in such a way that it is always inclined towards the ground; otherwise it would be a very great pest to mankind, for anyone on whom it fixes its eyes dies instantly. H 24 r.

BASILISK

It is found in the province of Cyrenaica and is not more than twelve fingers long. It has a white spot on its head of the shape of a diadem. It drives away every serpent by its whistling. It resembles a snake but does not move by wriggling, but extends itself straight forward from its centre. It is said that on one occasion when one of these was killed by a horseman's spear and its venom flowed over the spear, not only the man died but the horse did also. It spoils the corn, not only that which it touches but that upon which it breathes; it scorches the grass and splits the stones. H 24 r. and v.

WEASEL

This on finding the den of the basilisk kills it with the smell of its urine by spreading this about, and the smell of this urine often kills the weasel itself.

THE *CERASTE*

These have four small movable horns; and when they wish to feed they hide the whole of their body except these tiny horns under the leaves, and as they move these it seems to the birds that they are little worms wriggling about, and so they instantly descend and peck at them. And then the ceraste immediately wraps itself round them in a circle and so devours them. H 24 v.

AMPHISBOENA

This has two heads, one in its usual place the other at its tail, as though it was not sufficient for it to throw its poison from one place only.

JACULO

This stations itself in trees and hurls itself like a dart, and transfixes the wild beasts and slays them.

THE ASP

There is no remedy for the bite of this animal except instantly to cut away the part affected. Pestilential though it is this animal has so strong an affection for its companion that they always go in pairs. And if by a mischance one of them should be slain the other pursues the murderer with incredible speed, and is so alert and eager for vengeance as to overcome every obstacle. It will pass through a whole troop seeking only to wound its enemy, traversing any distance, and the only ways of avoiding it are by crossing over water or by a very rapid flight. Its eyes turn inwards and it has large ears, and its hearing guides it more than its sight. H 25 r.

ICHNEUMON

This animal is the mortal enemy of the asp. It is a native of Egypt, and when it sees an asp near to its place it runs instantly to the mud or slime of the Nile and covers itself with it entirely, and then after drying itself in the sun smears itself again with mud, and thus drying itself time after time covers itself with three or four coats like coats of mail; after this it attacks the asp and struggles with it determinedly, until it seizes its opportunity and flies at its throat and chokes it.

H 25 v.

CROCODILE

This is a native of the Nile. It has four feet and is dangerous both on land and in the water. It is the only land animal that is without a tongue, and it bites merely by moving its upper jaw. It grows to a length of forty feet, it has claws, and is covered with hide that will withstand any blow. It remains on land by day and in the water by night. When it has had its meal of fish it goes to sleep on the bank of the Nile with its mouth open, and then the bird called *trochilus*, a very small bird, runs immediately to its mouth, and hopping about among its teeth in and out proceeds to peck at the remains of its food, and causing it entrancing pleasure thereby tempts it to open its mouth more widely, and in so doing it falls asleep. No sooner does the ichneumon perceive this than it flings itself into its mouth, pierces its stomach and intestines, and so finally kills it. H 25 v. and 26 r.

DOLPHIN

Nature has given such power of understanding to animals that in addition to the perception of what is to their own advantage they know what is to the disadvantage of the enemy; as a consequence the dolphin knows both the power of a cut from the fins which it has on its back, and the tenderness of the belly of the crocodile, hence when they fight it glides underneath it, pierces its belly and so kills it.

The crocodile is terrifying to those who flee from him and an utter coward when he is being pursued. H 26 r.

HIPPOPOTAMUS

This when it feels itself becoming overloaded looks about for thorns or where there are the fragments of split canes, and there it rubs a vein so hard as to burst it open, and then having allowed as much blood to flow as may be necessary it besmears itself with mud and so plasters up the wound. It has almost the shape of a horse, with cloven hoofs, twisted tail, boar's tusks, and neck with flowing mane. The hide cannot be pierced except when it is bathing. It feeds on corn that grows in the fields, and makes its way into them backwards, so that it may appear that it has just emerged.

IBIS

This bears a resemblance to a stork, and when it feels ill it fills its crop with water and makes an injection with its beak.

STAG

This when it feels itself bitten by the spider called *phalangium* eats crabs and rids itself of the poison. H 26 v.

LIZARD

This when it fights with serpents eats sow-thistles and gains its freedom.

THE SWALLOW

This gives sight to its blind young with the juice of the celandine.

WEASEL

This when it chases rats eats first of rue.

WILD BOAR

This cures its diseases by eating ivy.

SERPENT

This when it wishes to renew itself casts its old slough, commencing by the head: it transforms itself in a day and a night.

PANTHER

This will still fight with the dogs and the hunters after its entrails have fallen out. H 27 r.

CHAMELEON

This always takes the colour of the object on which it is resting; as a consequence they are often devoured by the elephants together with the leaves on which they are resting.

CROW

This when it has slain the chameleon purges itself with laurel.
H 27 v.

XLIV

Allegory

'Loyalty. The cranes in order that their king may not perish by their keeping bad guard stand round him at night holding stones in their feet. Love, fear and reverence—write these upon the three stones of the crane.'

A MAN on seeing a large sword at another man's side said to him:—'Oh you poor fellow! I have been watching you now for a long time tied to this weapon. Why don't you release yourself since your hands are free, and thus regain your liberty?' To this the other made answer:—'This is not your affair, and in any case it is an old state of things.' The first feeling himself insulted said:—'I look on you as having a knowledge of so few matters in this world that I supposed that anything I could tell you would rank as new.' C.A. 13 r. d

Where fortune enters there envy lays siege and strives against it, and when this departs it leaves anguish and remorse behind.

When fortune comes seize her with a firm hand. In front, I counsel you, for behind she is bald. C.A. 76 v. a

A SIMILE OF PATIENCE

Patience serves as a protection against wrongs as clothes do against cold. For if you put on more clothes as the cold increases it will have no power to hurt you. So in like manner you must grow in patience when you meet with great wrongs, and they will then be powerless to vex your mind. C.A. 117 v. b

The spider, thinking to find repose within the keyhole, finds death.
C.A. 299 v. b

A simile. A vessel of unbaked clay when broken may be remoulded, but not one that has passed through the fire. Tr. 68 a

Fame should be represented in the shape of a bird, but with the whole figure covered with tongues instead of feathers. B 3 v.

By the cloth that is held by the hand in the current of a running stream, in the water of which it leaves all its impurities, is meant that . . .

By the thorn upon which are grafted good fruits is meant that which is not of itself predisposed to virtue, yet by the help of an instructor produces the most useful virtues.

One pushes down another: by these cubes [1] are represented the life and conditions of mankind. G 89 r.

Envy wounds by base calumnies, that is by slander, at which virtue is filled with dismay. H 60 [12] v.

Good Report soars and rises up to heaven, for virtuous things find favour with God. Evil Report should be shown inverted, for all her works are contrary to God and tend towards hell. H 61 [13] r.

The goldfinch will carry spurge to its little ones imprisoned in a cage: death rather than loss of liberty. H 63 [15] v.

[*For an allegorical representation*]

Il Moro with the spectacles and Envy represented with lying Slander, and Justice black for Il Moro.

Labour with the vine in her hand. H 88 [40] v.

The ermine with mud.

Galeazzo between time of tranquillity and flight of fortune.

The ostrich which with patience produces its young.

Bars of gold are refined in the fire. H 98 [44 bis v.] r.

Magnanimity. The falcon only takes the large birds, and will die rather than eat flesh that has become tainted.

Constancy. Not he who begins but he who endures.

H 101 [42 v.] r.

Loyalty. The cranes in order that their king may not perish by their keeping bad guard stand round him at night holding stones in their

[1] MS. has a diagram with dice.

feet. Love, fear and reverence—write these upon the three stones of the cranes. H 118 [25 v.] r.

The bee may be likened to deceit, for it has honey in its mouth and poison behind. I 49 [1] v.

[*For an allegorical representation*]

Il Moro as the figure of Fortune, with hair and robes and with hands held in front, and Messer Gualtieri with act of obeisance plucks him by the robes from below as he presents himself before him.

Also Poverty as a hideous figure running behind a youth, whom Il Moro covers with the skirt of his robe while he threatens the monster with his gilded sceptre. I 138 [90] v.

The evil that does not harm me is as the good that does not help me.

The rushes which hold back the tiny blades of straw when they are drowning. M 4 r.

[*With drawing of faggot*]

To place in the hand of ingratitude:

Wood feeds the fire that consumes it. MS. 2038 Bib. Nat. 34 r.

FOR INGRATITUDE

[*With drawing of man blowing out candle*]

When the sun appears which drives away the general darkness, you extinguish the light that drives away the particular darkness, for your necessity and convenience. B.M. 173 r.

Ivy is the [emblem] of longevity. Windsor: Drawings 12282 v.

Truth	the sun
falsehood	a mask
innocence	
malignity	

Fire destroys falsehood, that is sophistry, and restores truth, driving out darkness.

Fire is to be put for the destroyer of every sophistry and the revealer and demonstrator of truth, because it is light, the banisher of darkness which is the concealer of all essential things.

TRUTH

Fire destroys all sophistry, that is deceit; and maintains truth alone, that is gold.

Truth in the end cannot be concealed.

Dissimulation profits nothing. Dissimulation is frustrated before so great a judge.

Falsehood assumes a mask.

Nothing is hidden beneath the sun.

Fire is put for truth because it destroys all sophistry and lies, and the mask for falsity and lying by which the truth is concealed.

Windsor: Drawings 12700 v.

[*Sketch. Figures seated on clouds. Rain. Ground below strewn with implements*]

On this side Adam and on that Eve.

Oh human misery! of how many things do you make yourself the slave for money! Windsor: Drawings 12698 r.

This Envy is represented making a contemptuous motion towards heaven, because if she could she would use her strength against God. She is made with a mask upon her face of fair appearance. She is made wounded in the eye by palm and olive. She is made wounded in the ear by laurel and myrtle, to signify that victory and truth offend her. She is made with many lightnings issuing forth from her, to denote her evil speaking. She is made lean and wizened because she is ever wasting in perpetual desire. She is made with a fiery serpent gnawing at her heart. She is given a quiver with tongues for arrows, because with the tongue she often offends; and she is made with a leopard's skin, since the leopard from envy slays the lion by guile. She is given a vase in her hand full of flowers, and beneath these filled with scorpions and toads and other venomous things. She is made riding upon death, because envy never dying has lordship over him; and death is made with a bridle in his mouth and laden with various weapons, since these are all the instruments of death.

In the moment when virtue is born she gives birth to envy against herself, and a body shall sooner exist without a shadow than virtue without envy. Oxford Drawings, Part ii. No. 6

Pleasure and Pain are represented as twins, as though they were joined together, for there is never the one without the other; and they turn their backs because they are contrary to each other.

If you shall choose pleasure, know that he has behind him one who will deal out to you tribulation and repentance.

This is pleasure together with pain, and they are represented as twins because the one is never separated from the other.

They are made with their backs turned to each other because they are contrary the one to the other. They are made growing out of the same trunk because they have one and the same foundation, for the foundation of pleasure is labour with pain, and the foundations of pain are vain[1] and lascivious pleasures.

And accordingly it is represented here with a reed in the right hand, which is useless and without strength, and the wounds made with it are poisoned. In Tuscany reeds are put to support beds, to signify that here occur vain dreams, and here is consumed a great part of life: here is squandered much useful time, namely that of the morning when the mind is composed and refreshed, and the body therefore is fitted to resume new labours. There also are taken many vain pleasures, both with the mind imagining impossible things, and with the body taking those pleasures which are often the cause of the failing of life; so that for this the reed is held as representing such foundations.

Oxford Drawings, Part ii. No. 7

[1] MS., *vanj* not *varj*.

XLV

Prophecies

'Creatures shall be seen upon the earth who will always be fighting one with another, with very great losses and frequent deaths on either side. These shall set no bounds to their malice . . . O Earth! what delays thee to open and hurl them headlong into the deep fissures of thy huge abysses and caverns, and no longer to display in the sight of heaven so savage and ruthless a monster?'

COMMON HABIT

Some poor wretch will be flattered, and these same flatterers will always be to him deceivers, robbers and assassins.

THE PERCUSSION OF THE SUN'S DISC

Something will appear which will cover over the person who shall attempt to cover it.

OF MONEY AND GOLD

That shall come forth from hollow caves which shall cause all the nations of the world to toil and sweat with great agitation, anxiety and labour, in order to gain its aid.

OF THE FEAR OF POVERTY

The malevolent and terrifying thing shall of itself strike such terror into men that almost like madmen, while thinking to escape from it, they will rush in swift course upon its boundless forces.

OF ADVICE

He who shall be most necessary to whoever has need of him will be unknown, and if known will be held of less account. C.A. 37 v. c

OF SNAKES CARRIED BY SWANS

Serpents of huge size will be seen at an immense height in the air fighting with birds.

OF CANNON WHICH COME FORTH OUT OF A PIT AND FROM A MOULD

There shall come forth from beneath the ground that which by its terrific report shall stun all who are near it, and cause men to drop dead at its breath, and it shall devastate cities and castles.

C.A. 129 v. a

OF CHRISTIANS

There are many who hold the faith of the Son and only build temples in the name of the Mother.

OF FOOD WHICH HAS BEEN ALIVE

A large part of the bodies which have had life will pass into the bodies of other animals, that is the houses no longer inhabited will pass piece-meal through those which are inhabited, ministering to their needs and bearing away with them what is waste; that is to say that the life of man is made by the things which he eats, and these carry with them that part of man which is dead.

OF MEN WHO SLEEP UPON PLANKS MADE FROM TREES

Men will sleep and eat and make their dwelling among trees grown in the forests and the fields.

OF DREAMING

It shall seem to men that they see new destructions in the sky, and the flames descending therefrom shall seem to have taken flight and to flee away in terror; they shall hear creatures of every kind speaking human language; they shall run in a moment, in person, to divers parts of the world without movement; amidst the darkness they shall see the most radiant splendours. O marvel of mankind! What frenzy has thus impelled you! You shall hold converse with animals of every species, and they with you in human language. You shall behold yourselves falling from great heights without suffering any injury; the torrents will bear you with them as they mingle in their rapid course.

OF ANTS

Many communities there will be who will hide themselves and their young and their victuals within gloomy caverns, and there in dark places will sustain themselves and their families for many months without any light either artificial or natural.

OF BEES

And many others will be robbed of their store of provisions and their food, and by an insensate folk will be cruelly immersed and drowned. O justice of God! why dost thou not awake to behold thy creatures thus abused?

OF SHEEP, COWS, GOATS AND THE LIKE

From countless numbers will be stolen their little children, and the throats of these shall be cut, and they shall be quartered most barbarously.

OF NUTS, OLIVES, ACORNS, CHESTNUTS, AND THE LIKE

Many children shall be torn with pitiless beatings out of the very arms of their mothers, and flung upon the ground and then maimed.

OF CHILDREN WHO ARE WRAPPED IN SWADDLING BANDS

O cities of the sea, I behold in you your citizens, women as well as men, tightly bound with stout bonds around their arms and legs by folk who will have no understanding of our speech; and you will only be able to give vent to your griefs and sense of loss of liberty by making tearful complaints, and sighs, and lamentation one to another; for those who bind you will not have understanding of your speech nor will you understand them.

OF CATS THAT EAT RATS

In you, O cities of Africa! your own sons shall be seen torn to pieces within their own houses by most cruel and savage animals of your country.

OF ASSES WHICH ARE BEATEN

O neglectful Nature, wherefore art thou thus partial, becoming to some of thy children a tender and benignant mother, to others a most cruel and ruthless stepmother? I see thy children given into slavery to others without ever receiving any benefit, and in lieu of any reward for the services they have done for them they are repaid by the severest punishments, and they constantly spend their lives in the service of their oppressor.

DIVISION OF THE PROPHECIES

First of things which relate to the reasoning animals, second those which have not the power of reason, third of plants, fourth of ceremonies, fifth of customs, sixth of propositions, decrees or disputes, seventh of propositions contrary to Nature (as to speak of a substance which the more there is taken from it is the more increased), and reserve the weighty propositions until the end, and begin with those of less import, and show first the evils and then the punishments, eight of philosophical things. C.A. 145 r. a

OF FUNERAL RITES AND PROCESSIONS AND LIGHTS AND BELLS AND FOLLOWERS

The greatest honours and ceremonies shall be paid to men without their knowledge. C.A. 145 v. a

All the astrologers will be castrated, that is the cockerels.

C.A. 367 v. b

CONJECTURE

Arrange in order the months and the ceremonies which are performed, and do this for the day and for the night.

OF REAPERS

There will be many who will be moving one against another, holding in their hands the sharp cutting iron. These will not do each other any hurt other than that caused by fatigue, for as one leans forward the other draws back an equal space; but woe to him who intervenes between them, for in the end he will be left cut in pieces.

OF SILK-SPINNING

There shall be heard mournful cries and loud shrieks, hoarse angry voices of those who are tortured and despoiled and at last left naked and motionless; and this shall be by reason of the motive power which turns the whole.

OF PLACING BREAD WITHIN THE MOUTH OF THE OVEN AND DRAWING IT OUT AGAIN

In all the cities and lands and castles, villages and houses, men will be seen who through desire of eating will draw the very food out of each other's mouths, without their being able to make any resistance.

OF PLOUGHED LAND

The earth will be seen turned upside down and facing the opposite hemispheres, and laying bare the holes where lurk the fiercest animals.

OF SOWING

Then a great part of the men who remain alive will throw out of their houses the victuals they have saved, as the free booty of the birds and beasts of the field, without taking any care of them.

OF THE RAINS WHICH CAUSE THE RIVERS TO BECOME MUDDY AND CARRY AWAY THE SOIL

There will come from out the sky that which will transport a great part of Africa which lies beneath this sky[1] towards Europe, and that of Europe towards Africa; and those of the provinces will mingle together in great revolution.

OF BRICK-KILNS AND LIME-KILNS

At the last the earth will become red after being exposed to fire for many days, and the stones will become changed to ashes.

OF WOOD THAT IS BURNT

The trees and shrubs of the vast forests shall be changed to ashes.

OF BOILED FISH

Creatures of the water will die in boiling water.

THE OLIVES WHICH DROP FROM THE OLIVE-TREES GIVE US THE OIL WHICH MAKES LIGHT

There shall descend with fury from the direction of the sky that which will give us nourishment and light.

OF HORNED AND TAWNY OWLS WITH WHICH ONE GOES FOWLING WITH BIRD-LIME

Many will perish by fracturing their skulls, and their eyes will almost start out of their heads on account of fearsome creatures which have come forth out of the darkness.

OF FLAX WHEREBY PAPER IS MADE OUT OF RAGS

That shall be revered and honoured and its precepts shall be listened to with reverence and love, which was at first despised and mangled and tortured with many different blows.

[1] MS., *si mostra a esso cielo.*

OF BOOKS WHICH INCULCATE PRECEPTS

Bodies without souls shall by their sayings supply precepts which shall help us to die well.

OF THOSE WHO ARE BEATEN AND SCOURGED

Men will hide themselves within the bark of hollow trees, and there crying aloud they will make martyrs of themselves by beating their own limbs.

OF WANTONNESS

And they will go wild after the things that are most beautiful to seek after, to possess and make use of their vilest parts; and afterwards, having returned with loss and penitence to their understanding, they will be filled with great admiration for themselves.

OF THE AVARICIOUS

Many there will be who with the utmost zeal and solicitude will pursue furiously that which has always filled them with awe, not knowing its evil nature.

OF MEN WHO AS THEY GROW OLDER BECOME MORE MISERLY, WHEREAS, HAVING BUT A SHORT TIME TO STAY, THEY OUGHT TO BE MORE GENEROUS

You will see that those who are considered to be of most experience and judgment, in proportion as they come to have less need of things, seek and hoard them with more eagerness.

OF A DITCH (GIVE THIS AS AN INSTANCE OF FRENZY OR CRAZINESS OR MADNESS OF THE BRAIN)

There will be many busied in the practice of taking from that thing which increases the more the more they take from it.

OF WEIGHT PLACED ON A FEATHER-PILLOW

And with many bodies it will be seen that as you raise your head from them they will increase perceptibly, and when the head that has been lifted up returns, their size will immediately diminish.

OF CATCHING LICE

There will be many hunters of animals who the more they catch the fewer they will have; and so conversely they will have more in proportion as they catch less.

OF DRAWING WATER WITH TWO BUCKETS BY A SINGLE ROPE

And many will be busying themselves with a thing which the more they draw it up will tend the more to escape in the contrary direction.

OF SIEVES MADE OF THE SKIN OF ANIMALS

We shall see the food of animals pass through their skins in every way except through the mouth, and penetrate through the opposite side until it reaches the level ground.

OF THE LIGHTS THAT ARE CARRIED BEFORE THE DEAD

They will make light for the dead.

OF THE LANTERN

The fierce horns of powerful bulls will protect the light used at night from the impetuous fury of the winds.

OF FEATHERS IN BEDS

Flying creatures will support men with their feathers.

OF MEN WHO PASS ABOVE THE TREES WEARING WOODEN STILTS

The swamps will be so great that the men will go above the trees of their countries.

OF THE SOLES OF SHOES WHICH ARE OF LEATHER

Over a great part of the country men shall be seen walking about on the skins of large animals.

OF SAILING

There will be great winds through which the eastern things will become western, and those of the south mingled together in great measure by the course of the winds will follow these through distant lands.

OF THE WORSHIPPING OF PICTURES OF SAINTS

Men shall speak with men who shall not hear them; their eyes shall be open and they shall not see; they will speak to them and there shall be no reply; they will ask pardon from one who has ears and does not hear; they will offer light to one who is blind, and to the deaf they will appeal with loud clamour.[1]

OF DREAMING

Men shall walk without moving, they shall speak with those who are absent, they shall hear those who do not speak.

OF THE SHADOW THAT MOVES WITH MAN

There shall be seen shapes and figures of men and animals which shall pursue these men and animals wheresoever they flee; and the movements of the one shall be as those of the other, but it shall seem a thing to wonder at because of the different dimensions which they assume.

[1] MS., *faran lume a* [*chi*] *è orbo* [. . .] *sordi con gran* [. . .] *ore.*

OF THE SHADOW CAST BY THE SUN AND OF THE REFLECTION IN THE WATER SEEN AT ONE AND THE SAME TIME

Many times one man shall be seen to change into three and all shall proceed together, and often the one that is most real abandons him.

OF WOODEN COFFERS WHICH ENCLOSE MANY TREASURES

Within walnuts and other trees and plants there shall be found very great treasures which lie hidden there.

OF EXTINGUISHING THE LIGHT WHEN ONE GOES TO BED

Many by forcing their breath out too rapidly will lose the power of sight, and in a short time all power of sensation.

OF THE BELLS OF MULES WHICH ARE CLOSE TO THEIR EARS

There shall be heard in many parts of Europe instruments of various sizes making divers melodies, causing great weariness to those who hear them most closely.

OF ASSES

The many labours shall be repaid by hunger, thirst, wretchedness, blows and goadings.

OF SOLDIERS ON HORSEBACK

Many shall be seen carried by large animals with great speed, to the loss of their lives and to instant death. In the air and on the earth shall be seen animals of different colours, bearing men furiously to the destruction of their lives.

OF STARS ON SPURS

By reason of the stars you will see men moving as swiftly as any swift animal.

OF A STICK WHICH IS A DEAD THING

The movement of the dead shall cause many who are living to flee away with grief and lamentation and cries.

OF TINDER

With stone and iron things will be rendered visible which were not previous seen.

OF OXEN WHICH ARE EATEN

The masters of the estates will eat their own labourers.

OF BEATING THE BED TO REMAKE IT

To such a pitch of ingratitude shall men come that that which shall give them lodging without any price shall be loaded with blows, in such a way that great parts of the inside of it shall be detached from their place, and shall be turned over and over within it.

OF THINGS WHICH ARE EATEN WHICH ARE FIRST PUT TO DEATH

Those who nourish them will be slain by them and scourged by barbarous death.

OF THE WALLS OF CITIES REFLECTED IN THE WATER OF THEIR TRENCHES

The high walls of mighty cities shall be seen inverted, in their trenches.

OF THE WATER WHICH FLOWS IN A TURBID STREAM MINGLED WITH EARTH, AND OF DUST AND MIST MINGLING WITH THE AIR, AND OF THE FIRE WHICH MINGLES ITS HEAT WITH EACH

All the elements shall be seen confounded together, surging in huge rolling mass, now towards the centre of the earth, now towards the sky, at one time coursing in fury from the southern regions towards the icy north, at another time from the east to the west, and so again from this hemisphere to the other.

AT ANY POINT ONE MAY MAKE THE DIVISION OF THE TWO HEMISPHERES

All men will suddenly change their hemisphere.

EVERY POINT FORMS A DIVISION BETWEEN THE EAST AND THE WEST

All the animals will move from the east to the west, and so also from the north to the south.

OF THE MOVEMENT OF THE WATERS WHICH CARRY LOGS THAT ARE DEAD

Bodies without life will move of themselves and will carry with them innumerable generations of the dead, plundering the possessions of the living inhabitants.

OF EGGS WHICH BEING EATEN CANNOT PRODUCE CHICKENS

Oh! how many will those be who will never be born.

OF FISHES WHICH ARE EATEN WITH THEIR ROES

Endless generations will perish through the death of the pregnant.

OF THE BEASTS FROM WHOM CHEESE IS MADE

The milk will be taken from the tiny children.

OF THE LAMENTATIONS MADE ON GOOD FRIDAY

In all the parts of Europe there shall be lamentations by great nations for the death of one man.

OF THE HAFTS OF KNIVES MADE OF RAMS' HORNS

In the horns of animals shall be seen sharp irons, which shall take away the lives of many of their species.

OF THE NIGHT WHEN ONE CANNOT DISTINGUISH ANY COLOUR

It shall even come to pass that it will be impossible to tell the difference between colours, for all will become black in hue.

OF SWORDS AND SPEARS WHICH OF THEMSELVES NEVER DO ANY HARM TO ANYONE

That which of itself is gentle and void of all offence will become terrible and ferocious by reason of evil companionship, and will take the lives of many people with the utmost cruelty; and it would slay many more if it were not that these are protected by bodies which are themselves without life, which have come forth out of pits—that is by cuirasses of iron.

OF GINS AND SNARES

Many dead will move with fury, and will take and bind the living, and will set them before their enemies in order to compass their death and destruction.

OF THE PRECIOUS METALS

There shall come forth out of dark and gloomy caves that which shall cause the whole human race to undergo great afflictions, perils, and death. To many of those who follow it, after much tribulation it will yield delight; but whosoever pays it no homage will die in want and misery. It shall bring to pass an endless number of crimes; it shall prompt and incite wretched men to assassinate, to steal, and to enslave; it shall hold its own followers in suspicion; it shall deprive free cities of their rank: it shall take away life itself from many; it shall make men torment each other with many kinds of subterfuge, deceits, and treacheries.

O vile monster! How much better were it for men that thou shouldst go back to hell! For this the vast forests shall be stripped of their trees; for this an infinite number of creatures shall lose their lives.

OF FIRE

From small beginnings shall arise that which shall rapidly become great; and it shall have respect for no created thing, but its power shall be such as to enable it to transform almost everything from its natural condition.

OF SHIPS THAT FOUNDER

There shall be seen huge bodies devoid of life, carrying great numbers of men with fierce speed to the destruction of their lives.

C.A. 370 r. a

OF WRITING LETTERS FROM ONE COUNTRY TO ANOTHER

Men from the most remote countries shall speak one to another and shall reply.

OF THE HEMISPHERES WHICH ARE INFINITE AND DIVIDED BY AN INFINITE NUMBER OF LINES, IN SUCH A WAY THAT EVERY MAN HAS ALWAYS ONE OF THESE LINES BETWEEN HIS FEET

Men shall speak with and touch and embrace each other while standing each in different hemispheres, and shall understand each other's language.

OF PRIESTS WHO SAY MASS

Many shall there be who in order to practise their calling shall put on the richest vestments, and these shall seem to be made after the manner of aprons.

OF FRIARS WHO HOLD CONFESSION

The unhappy women of their own accord shall go to reveal to men all their wantonness and their shameful and most secret acts.

OF THE CHURCHES AND HABITATIONS OF FRIARS

There will be many who will abandon work and labour and poverty of life and possessions, and will go to dwell among riches and in splendid buildings, pretending that this is a means of becoming acceptable to God.

OF THE SELLING OF PARADISE

A countless multitude will sell publicly and without hindrance things of the very greatest value, without licence from the Lord of these things, which were never theirs nor in their power; and human justice will take no account of this.

OF THE DEAD WHO ARE TAKEN TO BE BURIED

The simple folk will carry a great number of lights to light up the journeys of all those who have wholly lost the power of sight. O human folly! O madness of mankind! These two phrases stand for the commencement of the matter.

OF THE DOWRIES OF MAIDENS

And whereas at first young maidens could not be protected from the lust and violence of men, either by the watchfulness of parents or by the strength of walls, there will come a time when it will be necessary for the fathers and relatives of these maidens to pay a great price to whoever is willing to marry them, even although they may be rich and noble and exceedingly beautiful. Herein it seems certain that Nature desires to exterminate the human race, as a thing useless to the world and the destroyer of all created things.

OF THE CRUELTY OF MAN

Creatures shall be seen upon the earth who will always be fighting one with another, with very great losses and frequent deaths on either side. These shall set no bounds to their malice; by their fierce limbs a great number of the trees in the immense forests of the world shall be laid level with the ground; and when they have crammed themselves with food it shall gratify their desire to deal out death, affliction, labours, terrors and banishment to every living thing. And by reason of their boundless pride they shall wish to rise towards heaven, but the excessive weight of their limbs shall hold them down. There shall be nothing remaining on the earth or under the earth or in the waters that shall not be pursued and molested or destroyed, and that which is in one country taken away to another; and their own bodies shall be made the tomb and the means of transit of all the living bodies which they have slain. O Earth! what delays thee to open and hurl them headlong into the deep fissures of thy huge abysses and caverns, and no longer to display in the sight of heaven so savage and ruthless a monster?

OF SAILING IN SHIPS

The trees of the vast forests of Taurus and of Sinai, of the Apennines and of Atlas, shall be seen speeding by means of the air from east to west, and from north to south, and transporting by means of the air a great quantity of men. Oh, how many vows! How many deaths! What partings between friends and relatives shall there be! How many who shall nevermore behold their own lands or their native country, and shall die unsepulchred and their bones be scattered in divers parts of the world!

OF REMOVING ON ALL SAINTS' DAY

Many shall leave their own dwellings, and shall carry with them all their goods and go to dwell in other lands.

OF ALL SOULS' DAY

How many will there be who will mourn for their dead ancestors, carrying lights for them!

OF FRIARS WHO BY SPENDING ONLY WORDS RECEIVE GREAT RICHES AND BESTOW PARADISE

Invisible money will cause many who spend it to triumph.

OF BOWS MADE FROM THE HORNS OF OXEN

Many there will be who by means of the horns of cattle will die a painful death. C.A. 370 v. a

Behold a thing which is valued the less the more one has need of it. It is advice. C 19 v.

And many have made a trade in deceits and feigned miracles, cozening the foolish herd, and if no one showed himself cognizant of their deceits they would impose them upon all. F 5 v.

FOR WELL-DOING

By the branch of the nut-tree which is struck and beaten just when it has brought its fruit to perfection, is represented those who as the sequel of their illustrious works are struck by envy in divers ways.
G 88 v.

All these things which in the winter are concealed and hidden beneath the snow, will be left bare and exposed in summer:—said of a lie which cannot remain hidden. I 39 v.

You will see the lion tribe tearing open the earth with hooked claws, and burying themselves in the holes that they have made, together with the other animals which are in subjection to them.

There shall come forth from the ground creatures clad in darkness who shall attack the human race with tremendous onslaughts, and it shall have the blood poisoned by their fierce bites even while it is devoured by them.

There shall also hurtle through the air a tribe of dreadful winged creatures who shall attack both men and beasts, and feed upon them with loud cries:—They shall fill their bellies full of crimson blood.
I 63 [15] r.

You will see the blood streaming forth from the rent flesh of men and bedewing the surface parts.

You will see men with so cruel a malady that they will tear their flesh with their own nails:—This will be the itch.

You will see plants continuing without leaves, and rivers standing still in their courses.

The water of the sea shall rise above the high summits of the mountains towards the sky, and it shall fall down again on to the dwellings of men:—That is as clouds.

You will see the greatest trees of the forests borne by the fury of the winds, from the east to the west:—That is across the sea.

Men shall cast away their own food:—That is in sowing.

I 63 [15] v.

The generation of men shall come to such a pass as not to understand one another's speech:—That is a German with a Turk.

You will see fathers giving up their daughters to the sensuality of men, and rewarding them, and abandoning all their former care:—When the girls are married.

Men shall come forth out of the graves changed to winged creatures, and they shall attack other men, taking away their food even from their hands and tables:—The flies.

Many there will be who will flay their own mother and fold back her skin:—The tillers of the ground.

Happy will be those who give ear to the words of the dead:—The reading of good works and the observing of their precepts.

I 64 [16] r.

Feathers shall raise men towards heaven even as they do birds:—That is by letters written with their quills.

The works of men's hands will become the cause of their death:—Swords and spears.

Men will pursue the thing they most fear:—That is they will be miserable lest they should fall into misery.

Things severed shall be united and shall acquire of themselves such virtue that they shall restore to men their lost memory:—That is the papyrus sheets, which are formed out of severed strips and preserve the memory of the thoughts and deeds of men.

You shall behold the bones of the dead by their rapid movement directing the fortunes of their mover:—The dice.

Oxen shall by their horns protect the fire from death:—The lantern.

The forests will bring forth young who will become the cause of their death:—The handle of the hatchet. I 64 [16] v.

Men will deal rude blows to that which is the cause of their life:—They will thrash the grain.

The skins of animals will make men rouse from their silence with loud cries and oaths:—Balls for playing games.

Many times the thing that is severed becomes the cause of great union:—That is the comb made up of split canes, which unites the threads in the silk.

The wind which passes through the skins of animals will make men leap up:—That is the bagpipes, which cause men to dance.

I 65 [17] r.

OF NUT-TREES WHICH ARE BEATEN

Those which have done best will be most beaten, and their children will be carried off and stripped or despoiled, and their bones broken and crushed.

OF SCULPTURE

Alas! whom do I see? The Saviour crucified again.

OF THE MOUTH OF MAN WHICH IS A TOMB

There shall come forth loud noises out of the tombs of those who have died by an evil and violent death.

OF THE SKINS OF ANIMALS WHICH HAVE THE SENSE OF FEELING OF WHAT IS WRITTEN THERE

The more you converse with skins covered over with sentiments, the more you will acquire wisdom.

OF PRIESTS WHO BEAR THE HOST IN THEIR BODIES

Then almost all the tabernacles where dwells the *Corpus Domini* will be plainly visible, walking about of themselves on the different roads of the world. I 65 [17] v.

And those who feed the air will turn night into day:—Tallow.

And many creatures of the earth and of the water will mount up among the stars:—The Planets.

You shall see the dead carrying the living in divers parts of the world:—The chariots and ships.

From many the food shall be taken away out of their mouths:—From ovens.

And those who have their mouths filled by the hands of others, shall have the food taken away out of their mouths:—The oven.

I 66 [18] r.

OF CRUCIFIXES WHICH ARE SOLD

I see Christ again sold and crucified, and his saints suffering martyrdom.

OF DOCTORS WHO LIVE UPON THE SICK

Men will come to such a state of misery that they will be grateful that others should profit by their sufferings, or by the loss of their true riches, that is health.

Of the religion of the Friars who live by means of the Saints, who have been dead for a long time:
Those who are dead will after a thousand years be those who will make provision for many of the living.

OF STONES CHANGED INTO LIME WITH WHICH PRISON WALLS ARE BUILT

Many things which have previously been destroyed by fire will deprive many men of their liberty. I 66 [18] v.

OF CHILDREN WHO TAKE THE BREAST

Many Franciscans, Dominicans, and Benedictines will eat that which has recently been eaten by others, and they will remain many months before being able to speak.

OF COCKLES AND SEA-SNAILS CAST UP BY THE SEA WHICH ROT WITHIN THEIR SHELLS

How many shall there be who after they are dead will lie rotting in their own houses, filling all the air around with their foul stench!

I 67 [19] r.

PLANT WITH ROOTS UPWARDS

For someone who would be on the point of coming to the end of all possessions and favour.

OF JACKDAWS AND STARLINGS

Those who trust themselves to inhabit near him, and these will be in great crowds, will almost all die a cruel death, and one will see fathers and mothers together with their families being devoured and slain by cruel animals. I 138 [90] v.

OF PEASANTS WHO WORK IN THEIR SHIRTS

Shadows will come from the East which will tinge with much darkness the sky that covers Italy.

OF THE BARBERS

All men will take refuge in Africa. I 139 [91] r.

OF THE SHADOW CAST BY MAN AT NIGHT WITH A LIGHT

There shall appear huge figures in human shape, and the nearer to you they approach the more will their immense size diminish.

K 50 [1] v.

OF MULES WHICH CARRY RICH BURDENS OF SILVER AND GOLD

Many treasures and great riches will be laid upon four-footed animals, which will carry them to divers places. L 91 r.

Those will be drowned who give light for divine service:—
The bees which make the wax of the candles.

The dead will come forth from under the earth, and by their fierce movements will drive innumerable human creatures out of the world:—
The iron which comes from under the earth is dead, and it makes the weapons wherewith so many men have been slain.

The greatest mountains, even though they are remote from the sea borders, will drive the sea from its place:—
That is by the rivers which carry down the soil they have taken from the mountains and deposit it upon the sea shores; and where the earth comes the sea retires.

The water fallen from the clouds will so change its nature as to remain for a long space of time upon the slopes of the mountains without making any movement. And this will happen in many and divers regions:—
The snow that falls in flakes which is water.

The great rocks of the mountains will dart forth fire, such that they will burn up the timber of many vast forests and many beasts both wild and tame:—
The flint of the tinder-box, which makes a fire that consumes all the loads of faggots of which the forests are cleared, and with this the flesh of beasts is cooked.

Oh! how many great buildings will be ruined by reason of fire:—
By the fire of the guns.

The oxen will become in great part the cause of the destruction of cities; and so also will horses and buffaloes:—
They draw the guns.

Many there will be who will wax great in their destruction:—
The ball of snow rolling over the snow.

There will be a great host who, forgetful of their existence and their name, will lie as though dead upon the spoils of other dead creatures:—
By sleeping upon the feathers of birds.

The east shall be seen to rush into the west, the south into the north, whirling themselves round about the universe with great noise, fury and trembling:—
The wind from the east which will rush into the west.

The rays of the sun will kindle fire on the earth, whereby that which is beneath the sky will be set alight; and, beaten back by that which impedes them, they will return downwards:—
The burning-glass kindles the fire with which the oven is heated, and this has its base standing beneath its vaulted roof.

A great part of the sea will fly towards the sky, and for a long time it will not return:—
That is in clouds. B.M. 42 V.

OF CORN AND OTHER SEEDS

Men shall throw away out of their houses those victuals which were meant for the sustenance of their lives:—[That is by sowing.]

OF TREES WHICH GIVE SAP TO GRAFTED SHOOTS

Fathers and mothers shall be seen to bestow much more attention upon their step-children than upon their own children.

OF THE THURIFER WITH INCENSE

Some shall go about in white vestments with arrogant gestures threatening others with metal and fire, which yet have never done them any harm. B.M. 212 V.

OF KIDS

The time of Herod shall return; for the innocent children shall be torn away from their nurses and shall die of great wounds at the hands of cruel men. Forster II 9 V.

OF THE MOWING DOWN OF GRASS

Innumerable lives will be extinguished, and innumerable vacant spaces created upon the earth.

OF THE LIFE OF MEN WHO EVERY TEN YEARS ARE CHANGED IN BODILY SUBSTANCE

Men will pass when dead through their own bowels.

OF SKINS

Many animals . . . Forster II 34 r.

OF LEATHER BOTTLES

The goats will carry wine to the cities. Forster II 52 v.

OF SHOEMAKERS

Men will take a pleasure in seeing their own works worn out and destroyed. Forster II 61 v.

OF BEES

They live together in communities. They are drowned in order that their honey may be seized.

Many and very great communities will be drowned in their own dwellings. Windsor: Drawings 12587 r.

Snow in summer shall be gathered on the high mountain peaks and carried to warm places, and there be let to fall down, when festivals are held in the piazza in the time of summer. Sul Volo 14 [13] r.

XLVI

Personalia

'O Leonardo, why do you toil so much?'

To WRITE thus clearly of the kite would seem to be my destiny, because in the earliest recollections of my infancy it seemed to me when I was in the cradle that a kite came and opened my mouth with its tail, and struck me within upon the lips with its tail many times. C.A. 66 v. b

Pray hold me not in scorn! I am not poor!

Poor rather is the man who desires many things.

Where shall I take my place? Where in a little time from henceforth you shall know. Do you answer for yourself! From henceforth in a little time . . . C.A. 71 r. a

If it is said that the King lacks seventy-two ducats of revenue when this water is drawn off from San Cristoforo. . . .

This His Majesty knows: what he gives me he takes from himself.

But in this instance nothing will be taken from the King, but it will be taken away from him who has stolen it, because of the regulation of the exits which the thieves of the water have enlarged.

If it should be said that this causes loss to many, it amounts to nothing more than taking away from the thieves what they have to restore.

And indeed the magistrate continually takes this away again without any thought of me, and it exceeds five hundred ounces of water, whereas for me it is fixed only at twelve ounces.

And if it should be said that this right of water of mine is worth a considerable sum in the year, the ounce here when the canal is so low is let at only seven ducats of four lire each, one per ounce per year, and this amounts to seventy.

If they say that this hinders navigation this is not true, because the mouths which serve for this irrigation are above the navigation.

C.A. 93 r. a

The Medici created and destroyed me. (*li medici mi creorono e disstrussono.*)[1] C.A. 159 r. c

Note as to the moneys I have had from the King on account of my salary from July 1508 until April 1509. First 100 crowns, then another 100, then 70, then 50 and then 20, and then 200 francs, a franc being worth 48 soldi. C.A. 192 r. a

Tell me if ever, tell me if ever anything was built in Rome . . . C.A. 216 v. b

AT ROME

At old Tivoli. Hadrian's Villa.[2] C.A. 227 v. a

Find Ligny (*Ingil*)[3] and tell him you will wait for him at Rome (*a morra*),[3] and will go with him to Naples (*in lo panna*).[3] See that you make the donation (*e no igano dal*),[3] and take the book of Vitolone, and the measurements of the public buildings. Have two trunks covered ready for the muleteer; bed-spreads will do very well for the purpose; there are three of them but you will leave one at Vinci. Take the stoves from the Grazie. Get from Giovanni Lombardo the [model of] the theatre of Verona. Buy some table-cloths and towels, hats, shoes, four pairs of hose, a great coat of chamois hide, and leather to make new ones. The turning-lathe of Alessandro. Sell what you cannot carry. Get from Jean de Paris the method of colouring in tempera, and the way

[1] This interpretation is due to Gerolamo Calvi, who considers the note to have been written in the last years of Leonardo's life, either when on the point of departing from Rome or in France. His patron Giuliano de'Medici had died and the Medici Pope, Leo X, had failed to give him any employment commensurate with his powers. He thus sets in terse antithesis this destruction of his hopes and the fact that Lorenzo il Magnifico was his first patron. The latter statement is confirmed by the testimony of the Anonimo Gaddiano:—*'stette da giovane col Magnifico Lorenzo de'Medici, et dandolj provisione per se il faceva lavorare nel giardino sulla piaza di san Marcho dj Firenze, et haveva* 30 *annj, che dal detto Magnifico Lorenzo fu mandato al duca di Milano.'*

The sentence has also been held to refer to the medical profession to whom on occasion he alludes with marked asperity. In MS. F 96 v. he characterises them as 'destroyers of life'. In Arundel MS. 147 v. he speaks of men being chosen to be doctors for diseases about which they do not know.

[2] On the same page of MS. occurs the line

Laus Deo 1500 *a di* [. . .] *marzo.*

The juxtaposition does not however warrant any supposition as to a visit to Rome of about this date.

[3] In MS. these words, presumably for reasons of secrecy, were written backwards.

of making white salt, and tinted papers either single or with many folds, and also his box of colours. Learn how to work flesh tints in tempera. Learn how to melt gum into lacquer-varnish. Take seed of... (*fotteragi*), of white cudweed[?] (*gniffe*) and of garlic from Piacenza. Take the 'De Ponderibus'. Take the works of Leonardo of Cremona. Carry the charcoal-burner which belongs to Giannino. Take the seed of lilies, of common lady's mantle, and of water-melon. Sell the boards of the scaffolding. Give the stove to whoever stole it. Learn levelling, how much soil a man can dig out in a day. C.A. 247 r. a

A certain ignoramus puffed up in obscurity, as is the gourd or the melon through excess of moisture or the plum swollen by the heavy showers. No! you have not described him well, don't you know [...]; he is an absolute fool [...] shaven head; but he lacks the cabbage [1] or the leaf of a gourd to loosen the scurf.

Say on, Sandro! [2] How does it strike you? I tell you what is true, and I have not made a success of it. C.A. 313 r. b

[*A list of drawings*]

Many flowers drawn from nature.
A head full-face with curly hair.
Various Saint Jeromes.
The measurements of a figure.
Drawings of furnaces.
A head of the duke.
Many drawings of knots.
Four drawings for the altar-piece of Sant' Angelo.
A little history of Girolamo da Feghine.
A head of Christ done with the pen.
Eight Saint Sebastians.
Many studies of angels.
A chalcedony.
A head in profile with beautiful hair.
Some bodies in perspective.
Some instruments for ships.

[1] *Il cavolo* (cabbage). Compare perhaps *mangiare il cavolo co' ciechi* (to have business with very silly people). Hoare, Ital. Dict.

[2] The reference may be to Sandro Botticelli.

Some machines for water.
A head-portrait of Atalanta raising her face.
The head of Hieronymo da Feglino.
The head of Gian Francesco Boso.
Many throats of old women.
Many heads of old men.
Many nudes, whole figures.
Many arms, legs, feet, and positions.
A Madonna, finished.
Another, almost in profile.
The head of the Madonna ascending into Heaven.
The head of an old man, very long.
A head of a gipsy woman.
A head with a hat on.
A history of the Passion made in a mould.
A head of a girl with tresses gathered in a knot.
A head with a coiffure.
A head of a youth, full face, with beautiful hair. C.A. 324 r. a

All the animals languish, filling the air with lamentations. The woods fall in ruin. The mountains are torn open, in order to carry away the metals which are produced there. But how can I speak of anything more wicked than [the actions] of those who raise hymns of praise to heaven for those who with greater zeal have injured their country and the human race? C.A. 382 v. a

These piles should be from a third to half a braccio in thickness and about two and a half braccia long; they should be of oak or alder, that is of some close-grained wood, and most important of all they should be green. I have watched the repair of part of the old walls of Pavia which have their foundations in the banks of the Ticino. The piles there which were old and were of oak were as black as charcoal, those which were of alder had a red colour like Brazil-wood; they were of considerable weight and as hard as iron, without any blemish. And when you wish to drive in these piles you should make the beginning of the hole for it with an iron stake. B. 66 r.

[*Dated Note. Thefts of pupil. Pageant ararnged by Leonardo*]

On the twenty-third day of April 1490 I commenced this book and recommenced the horse.

Giacomo came to live with me on St. Mary Magdalene's Day,[1] 1490, when ten years of age. Thievish, lying, obstinate, greedy.

The second day I had two shirts cut out for him, a pair of hose and a doublet, and when I put money aside to pay for these things he stole the money from the wallet, and it was never possible to make him confess, although I was absolutely convinced. 4 lire.

On the following day I went to supper with Giacomo Andrea, and the other Giacomo had supper for two and did mischief for four, for he broke three flagons, spilt the wine, and after this came to supper where I . . .

Item, on the seventh day of September he stole a style worth twenty-two soldi from Marco who was with me. It was of silver, and he took it from his studio. After the said Marco had searched for it a long time he found it hidden in the box of the said Giacomo. 2 lire 1 soldo.

Item, on the twenty-sixth day of the following January when I was in the house of Messer Galeazzo da Sanseverino in order to arrange the pageant at his tournament, and certain of the pages had taken off their clothes in order to try on some of the costumes of the savages who were to appear in this pageant, Giacomo went to the wallet of one of them as it lay on the bed with the other effects, and took some money that he found there. 2 lire 4 soldi.

Item, a Turkish hide had been given me in the same house by the Master Agostino of Pavia in order to make a pair of boots, and this Giacomo stole it from me within a month and sold it to a cobbler for twenty soldi, and with the money as he has himself confessed to me he bought aniseed comfits. 2 lire.

Item, further on the second day of April Giovanni Antonio chanced to leave a silver style upon one of his drawings, and this Giacomo stole it from him, and it was worth twenty-four soldi. 1 lira 4 soldi.

The first year: a cloak 2 lire, 6 shirts 4 lire, 3 doublets 6 lire, 4 pairs of hose 7 lire 8 soldi, a suit of clothes lined 5 lire, 24 pairs of shoes 6 lire 5 soldi, a cap 1 lira, laces for belt 1 lira. C 15 v.

[1] Twenty-second of July.

When I was at sea in a position equally distant from a level shore and a mountain, the side on which the shore was, seemed much farther off than that of the mountain.[1] L 77 v.

Like a eddying wind scouring through a hollow, sandy valley, and with speeding course driving into its vortex everything that opposes its furious onset . . .

Not otherwise does the northern blast drive back with its hurricane . . .

Nor does the tempestuous sea make so loud a roaring when the northern blast beats it back in foaming waves between Scylla and Charybdis, nor Stromboli nor Mount Etna when the pent up, sulphurous fires, bursting open and rending asunder the mighty mountain by their force, are hurling through the air rocks and earth mingled together in the issuing belching flames. . . .

Nor when Etna's burning caverns vomit forth and give out again the uncontrollable element, and thrust it back to its own region in fury, driving before it whatever obstacle withstands its impetuous rage. . . .

And drawn on by my eager desire, anxious to behold the great abundance of the varied and strange forms created by the artificer Nature, having wandered for some distance among the overhanging rocks, I came to the mouth of a huge cavern before which for a time I remained stupefied, not having been aware of its existence, my back bent to an arch, my left hand clutching my knee, while with the right I made a shade for my lowered and contracted eyebrows; and I was bending continually first one way and then another in order to see whether I could discern anything inside, though this was rendered impossible by the intense darkness within. And after remaining there for a time, suddenly there were awakened within me two emotions, fear

[1] In the sketch that accompanies this note a vessel is seen proceeding from a mountainous shore to one more low-lying. The note is designated by M. Ravaisson-Mollien 'an optical delusion'. Its major interest is in the biographical question it raises. That Leonardo was himself once at sea in a position equally distant between a level and a mountainous shore, both visible at once, is here clearly stated. In discussing the interpretation of the Armenian letters in the Codice Atlantico (*The Mind of L. da V.*, p. 232, etc.) I have shown that the experience is such as would befall a traveller journeying from Khelindreh, the medieval port of Armenia, mentioned in Leonardo's text as Calindra, to Cyprus, which is referred to in a passage in the Windsor Manuscripts, 'setting out from the coast of Cilicia towards the south you discover the beauty of the island of Cyprus'.

and desire, fear of the dark threatening cavern, desire to see whether there might be any marvellous thing therein. B.M. 155 r.

O powerful and once living instrument of constructive Nature, thy great strength not availing thee, thou must needs abandon thy tranquil life to obey the law which God and time ordained for all-procreative Nature! To thee availed not the branching, sturdy dorsal fins wherewith pursuing thy prey thou wast wont to plough thy way, tempestuously tearing open the briny waves with thy breast.

O how many times the frightened shoals of dolphins and big tunny-fish were seen to flee before thy insensate fury; and thou, lashing with swift, branching fins and forked tail, didst create in the sea sudden tempest with loud uproar and foundering of ships; with mighty wave thou didst heap up the open shores with the frightened and terrified fishes, which thus escaping from thee were left high and dry when the sea abandoned them, and became the plenteous and abundant spoil of the neighbouring peoples.

. . . . .

O Time, swift despoiler of created things! How many kings, how many peoples hast thou brought low! How many changes of state and circumstance have followed since the wondrous form of this fish died here in this hollow winding recess? Now, destroyed by Time, patiently it lies within this narrow space, and, with its bones despoiled and bare, it is become an armour and support to the mountain which lies above it.
B.M. 156 r.

O how many times hast thou been seen amid the waves of the mighty, swelling ocean, towering like a mountain, conquering and overcoming them! And with black-finned back ploughing through the salt waves with proud and stately bearing! [1] C.A. 265 r. a

Tell me if anything was ever made . . . B.M. 251 v.

[1] This passage is placed here because of its evident connection with the two that precede it. They may be a personal reminiscence or an imaginary tale.

There are three versions of this passage in the manuscript:—

Oh quante volte fusti tu veduto in fra l'onde del gonfiato e grande occeano, col setoluto e nero dosso, a giusa di montagna, e con grave e superbo andamento.

E spesse volte eri veduto in fra l'onde del gonfiato e grande occeano, e col superbo e

EXPENSES FOR CATERINA'S BURIAL

For three pounds of wax	s.	27
For the bier	s.	8
Pall upon the bier	s.	12
Carrying and setting up of cross	s.	4
For the carrying of the dead	s.	8
For four priests and four clerks	s.	20
Bell, book, sponge	s.	2
For the gravediggers	s.	16
To the ancient	s.	8
For the licence and the officials	s.	1
		106
For the doctor		5
Sugar and candles	s.	12
		123

Forster II 64 v.

If liberty is dear to you, may you never discover that my face is love's prison. Forster III 10 v.

Finally through anger he has wounded the image of his God; think if I had found him.

And that which he cannot eat he sells, in order by these coins to be able to have command over the other men. Forster III 85 r.

[*Vices hard to extirpate*]

And in this case I know that I shall make few enemies, for no one will believe what I can say of him. For there are few whom his vices displease, in fact only those who are by nature averse to these vices. And many hate their fathers and break off friendships when they are

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grave moto gir volteggiando in fralle marine acque. E con setoluto e nero dosso, a guisa di montagna, quelle vincere e soprafare.

Oh quante volte fosti tu veduto in fra l'onde del gonfiato e grande occeano, a guisa di montagna quelle vincere e soprafare, e col setoluto e nero dosso solcare le marine acque, e con superbo e grave andamento.

It is the same indefatigible patience seen in the attempt here in the armoury of words to fashion the thought to more exact expression, of the purpose of the mind which explains why there are sometimes so many studies for the same figure in Leonardo's drawings.

reproved for their vices; instances to the contrary have no weight with them, nor has any human counsel. Quaderni II 14 r.

[*Wealth of words a difficulty*]

I have so many words in my mother-tongue that I ought rather to complain of the lack of a right understanding of things, than of a lack of words with which fully to express the conception that is in my mind. Quaderni II 16 r.

I have wasted my hours.[1] Quaderni III 12 v.

I once saw how a lamb was licked by a lion in our city of Florence, where there are always from twenty-five to thirty of them, and they bear young. With a few strokes of his tongue the lion stripped off the whole fleece with which the lamb was covered, and having thus made it bare he ate it. Quaderni IV 9 v.

Tell me if anything similar was ever made: you understand, and that is enough for the present.[2] Quaderni IV 15 v.

Blue colour of the atmosphere . . . may be seen, as I myself saw it, by anyone who ascends Mon Boso [Monte Rosa], a peak of the chain of Alps that divides France from Italy. . . . The hail that accumulates there in summer I found very thick in the middle of July. Leic. 4 r.

In the mountains of Parma and Piacenza, multitudes of shells and corals filled with wormholes may be seen still adhering to the rocks.

When I was making the great horse at Milan a large sack of those which had been found in these parts was brought to my workshop by some peasants, and among them were many still in their original condition. Leic. 9 v.

There are, in many places, springs of water which rise for six hours and sink for six hours; and I have myself seen one above Lake Como called Fonte Pliniana. Leic. II v.

[1] Note written on the right-hand lower corner of a page that contains mathematical and architectural drawings, and others anatomical of the generative functions, with acoustical note and memoranda.

[2] This is on the same page with reduction of periphery of quadrant to straight line and calculation of spheres.

On one occasion above Milan, over in the direction of Lake Maggiore, I saw a cloud shaped like a huge mountain made up of banks of fire, because the rays of the sun which was then setting red on the horizon had dyed it with their colour. This great cloud drew to itself all the little clouds which were round about it. And the great cloud remained stationary, and it retained the light of the sun on its apex for an hour and a half after sunset, so enormous was its size. Leic. 28 r.

XLVII

Letters

'There is not a man who is capable—and you may believe me—except Leonardo the Florentine who is making the bronze horse of the Duke Francesco; and you can leave him out of your calculations altogether, for he has a work to do which will last him the whole of his life, and indeed I doubt whether he will ever finish it, so great it is.'

Bernardo di Simone.

As I told you in days past you know that I am without any . . . of the friends . . . and the winter . . . which requires your deeds.

C.A. 4 v. b

Dearest father,

On the last of the past month I had the letter you wrote to me which in a brief space caused me pleasure and also sorrow. I was pleased at learning from it that you were in good health, for which God be praised. I was filled with sorrow at hearing of your discomfort.

C.A. 62 v. a

[*Fragment of letter written while at Rome*]

I have satisfied myself that he accepts commissions from all and has a public shop; for which reason I do not wish that he should work for me at a salary, but that he should be paid for the works that he does for me; and since he has workshop and house from the Magnifico he should be obliged to give precedence to the works for the Magnifico before all.

C.A. 92 r. b

THE DIVISIONS OF THE BOOK

The preaching and persuasion of faith.

The sudden inundation down to its end.

The ruin of the city.
The death of the people and their despair.
The pursuit of the preacher and his liberation and benevolence.
Description of the cause of this fall of the mountain.
The havoc that it made.
The avalanche.
The finding of the prophet.
His prophecy.
The inundation of the lower parts of western Armenia, the channels in which were formed by the cutting of Mount Taurus.
How the new prophet showed that this destruction occurred as he had foretold.

Description of Mount Taurus and of the river Euphrates. To the Devatdar of Syria, lieutenant of the sacred Sultan of Babylon:

The recent unforeseen event which has occurred in these our northern parts which I am certain will strike terror not only into you but into the whole world shall be revealed to you in its due order, showing first the effect and then the cause.

Finding myself in this part of Armenia in order to discharge with devotion and care the duties of that office to which you have appointed me, and making a beginning in those parts which seem to me to be most suitable for our purpose, I entered into the city of Calindra which is near to our borders. This city is situated on the sea-coast of that part of the Taurus range which is separated from the Euphrates and looks westward to the peaks of the great Mount Taurus. These peaks are of such a height that they seem to touch the sky, for in the whole world there is no part of the earth that is higher than their summit, and they are always struck by the rays of the sun in the east four hours before day. And being of exceedingly white stone this shines brightly and performs the same office for the Armenians of these parts as the beautiful light of the moon would in the midst of the darkness; and by reason of its great height it outstretches the highest level of the clouds for a space of four miles in a straight line.

This peak is visible from a great part of the west illuminated by the sun after its setting during the third part of the night. And it is this which among you in calm weather has formerly been thought to be a comet, and seems to us in the darkness of the night to assume various shapes, sometimes dividing into two or three parts, sometimes long and sometimes short. And this proceeds from the fact that the clouds on the horizon come between part of this mountain and the sun, and by their cutting these solar rays the light of the mountain is broken by various spaces of clouds and therefore its brightness is variable in shape.

Why the mountain shines at its summit half or a third of the night, and seems a comet after sunset to those who dwell in the west, and before sunrise to those who dwell in the east.

Why this comet seems variable in shape, so that at one time it is round, at another long, at another divided into two or three parts, at another united, and sometimes invisible and sometimes becoming visible again. C.A. 145 v. a

OF THE SHAPE OF MOUNT TAURUS

I am not justly to be accused of idleness, O Devatdar, as your strictures seem to intimate, but your unbounded affection which has caused you to confer these benefits upon me has constrained me to employ the utmost care in seeking out and diligently investigating the cause of so momentous and so startling an occurrence, and for this time was necessary.

In order now to make you well acquainted with the cause of so great an effect it is necessary that I shall describe the nature of the place, and then I will proceed to the event, by which process I believe you will be fully satisfied.

Do not distress yourself, O Devatdar, at my delay in replying to your urgent request, because the matters about which you have asked me are of such a nature as cannot well be expressed without lapse of time, and especially because in wishing to expound the cause of so great an effect it is necessary to describe exactly the nature of the place, and you will afterwards be able by means of this easily to satisfy yourself as to the above-mentioned request.

I will omit any description of the shape of Asia Minor, or of what seas or lands they are which determine the aspect of its surface, knowing as I do your diligence and care in your studies to be such that you will already have acquired this knowledge; I pass on therefore to furnish you with an account of the true shape of Mount Taurus which has been the scene of so surprising and destructive a catastrophe, for this may serve to advance our purpose.

It is this Mount Taurus which, according to many, is said to be the ridge of the Caucasus, but, wishing to be quite clear about this, I set myself to interrogate some of the inhabitants of the shores of the Caspian Sea; and they inform me that although their mountains bear the same name these are of greater height, and they confirm this therefore to be the true Mount Caucasus, since Caucasus in the Scythian tongue means 'supreme height'. And in fact nothing is known of the existence either in the east or the west of any mountain of so great a height, and the proof of this is that the inhabitants of those countries which are on the west see the sun's rays illuminating part of its summit for a fourth part of the longest night, and similarly with the countries which are on the east.

OF THE STRUCTURE AND DIMENSIONS OF MOUNT TAURUS

The shadow of this ridge of the Taurus is so high that in the middle of June when the sun is at the meridian it reaches to the borders of Sarmatia, which are twelve days' journey, and in mid-December it extends as far as the Hyperborean Mountains, which are a month's journey to the north. And the side that faces the way the wind blows is full of clouds and mists, because the wind which is cleft in twain as it strikes against the rock and closes up again beyond it, carries with it in this way the clouds from all parts and leaves them where it strikes, and it is always full of thunderbolts through the great number of clouds which are gathered there, and this causes the rock to be all fissured and filled with huge débris.

This mountain at its base is inhabited by a very opulent people; it abounds in most beautiful springs and rivers; it is fertile and teems with everything that is good and especially in those parts which have a southern aspect. After an ascent of about three miles, you come to where begin the forests of great firs and pines and beeches and other similar trees; beyond for a space of another three miles you find meadows and vast pastures, and all the rest as far as the beginning of the peak of Taurus is eternal snow, for this never disappears in any season, and it extends at this height for about fourteen miles in all. From the point where the peak begins for about a mile the clouds never pass, so that they extend for about fifteen miles with a height of about five in a straight line. As far beyond or thereabouts we find the summit of the peaks of Taurus, and here from about half way upwards we commence to find the air grow warm, and there is no breath of wind to be felt and nothing can live there very long. Nothing is brought forth there except some birds of prey, which nest in the deep gorges of the Taurus and descend below the clouds to seek their prey upon the grassy hills. It is all bare rock from above where the clouds are, and the rock is of a dazzling whiteness, and it is not possible to go to the lofty summit because the ascent is rough and dangerous. C.A. 145 v. b

People were to be seen who in a state of great excitement were bringing together all sorts of provisions upon vessels of all descriptions hastily put together as necessity dictated.

The gleaming of the waves was not visible in the parts that reflected the dark rain and the clouds. But where they reflect the flashes produced by the thunderbolts, as many gleams were seen caused by the images of these flashes as were the waves that reflected them to the eyes of the spectators. And the number of the images caused by the flashes of the lightning upon the waves of the water increased in proportion to the distance of the eyes of the spectators. Similarly also the number of the images diminished in proportion as they were nearer to the eyes which saw them; as is proved in the definition of the radiance of the moon and of our maritime horizon, when the sun is reflected there with its rays and the eye which receives this reflection is at a great distance from this sea. C.A. 155 r. b

I wished to keep him to eat with me, as . . .

He went to eat with the bodyguard, and through this not only did he spend two or three hours at table, but very frequently the remainder of the day was spent in going about with a gun amid the ruins killing birds.

And if any of my servants entered the workshop he abused them, and if anyone reproved him he said that he was working for the arsenal cleaning armour and guns. As regards money, right from the very beginning of the month he was very eager to get hold of it.

And in order not to be disturbed he left the workshop and made himself one in his room, and worked for others, and so at last I had to tell him . . .

As I saw that he was very little in the workshop and consumed a good deal, I sent a message to him that if it pleased him I would strike a bargain with him for whatever he made, and have it valued, and I would then give him as much as we agreed upon: he took counsel with his neighbour and gave up his room, selling everything and came to look for . . .

This other has hindered me in anatomy before the Pope, traducing me, and also with the hospital; and he has filled the whole of this Belvedere with workshops for mirrors, and workmen, and he has done the same in the apartment of the master Giorgio.

He never did any work without discussing it every day with Giovanni, who then spread the news of it and proclaimed it everywhere, stating that he was a master of such art; and as regards the part which he did not understand he announced that I did not know what I wanted to do, thus shifting the blame of his ignorance upon me.

I cannot make anything secretly because of him, for the other is always at his elbow, since the one room leads into the other. But his whole intent was to get possession of these two rooms in order to get to work on the mirrors. And if I set him there to make my model of a curved one he would publish it.

He said that he had been promised eight ducats per month, to commence from the first day that he set out, or at latest from when he had his interview with you, and that you agreed to this. C.A. 182 V. C

My most beloved brother,[1]

This is sent merely to inform you that a short time ago I received a letter from you from which I learnt that you have had an heir, which circumstance I understand has afforded you a great deal of pleasure. Now in so far as I had judged you to be possessed of prudence I am now entirely convinced that I am as far removed from having an accurate judgment as you are from prudence; seeing that you have been

[1] Reference, according to Beltrami, is to Domenico who was born in 1484.

congratulating yourself in having created a watchful enemy, who will strive with all his energies after liberty, which can only come into being at your death. C.A. 202 V. a

You wished the utmost evil to Francesco and have let him enjoy your property in your life; to me you do not wish great evil . . .

To whom have you wished better? To Francesco or to me? To you he wishes it, and he gives mine after me so that I cannot act according to my wish, and he knows that I cannot alienate my heir. He wishes then to demand from my heirs and not as F., but as one entirely alien, and I as one entirely alien will receive him and his.

Have you given such money to Leonardo? No. Oh what excuse whether feigned or true will you be able to give for having drawn him into this trap, except to take him and his money. And I will not say anything to him as long as he lives. You do not wish therefore to repay the money lent on your account to his heirs; but you wish that he should pay over the revenues that he has from this possession.

Oh why do you not allow him to enjoy them during his life, since afterwards they would return to your children, and he cannot live many years?

If then you take into account that I may do that, you will wish that I was the heir, because I should not be able as heir to demand from you the moneys which I had had from Francesco. C.A. 214 V. a

As I have in my letters rejoiced with you many times over your prosperous fortunes so I know now that you as a friend will share my sorrow at the miserable condition to which I am reduced; for the fact is that in these last days I have had so many anxieties, so many fears, dangers and losses, as have also the wretched country-folk, that we have come to envy the dead.

And certainly I for my part cannot imagine that since first the elements by their separation made order out of chaos, they can ever have united their force or rather their frenzy to work such destruction to mankind, as has now been seen and experienced by us; so that I cannot imagine what could further increase so great a misfortune as this that we have experienced in a space of ten hours. First we were assailed and buffeted by the might and fury of the winds, and then followed the avalanches from the great snow-covered mountains which have choked up all these valleys, and caused a great part of this city to fall in ruins. And, not content with this, the tempest has submerged with a sudden deluge of water all the lower parts of the city; and beyond all this there was added a sudden storm of rain and a furious hurricane, laden with water, sand, mud, and stones all mingled together with roots, branches, and stumps of various trees; and every kind of thing came hurtling through the air and descended upon us, and finally a great fire—which did not seem to be borne by the wind but as though carried by thirty thousand devils—has burnt up and destroyed all this country and has not yet ceased. And the few of us who remain are left in such a state of dismay and fear that, like those who are half-witted, we scarce dare to hold speech one with another, but giving up even the attempt at work we stay huddled together in the ruins of some of the churches, men and women small and great all mingled together like herds of goats; and but for certain people having helped us with provisions we should all have died of hunger. Now you can understand the state we are in; and yet all these evils are as nothing by comparison with those which threaten us within a brief space of time.

I know that you as a friend will have a fellow-feeling for my misfortunes, even as I in my former letters have shown myself glad at your prosperity.[1] C.A. 214 v. d

[*Drafts of parts of a letter to the Venetian Senate concerning the defences of the Isonzo against the Turks*] [2]

My most illustrious Lords,

As I have perceived that the Turks cannot invade Italy by any part of the mainland without crossing the river Isonzo . . . and although I know that it is not possible to devise any means of protection which shall endure for any length of time, I cannot refrain from bringing to your notice the fact that a small number of men aided by this river might do the work of many, seeing that where these rivers . . .

I have formed the opinion that it is not possible to make a defence

[1] From the subject matter of this letter it would seem to have been written at about the same time as those to the Devatdar of Syria.

[2] All this letter is crossed out in MS. Passages in brackets have been crossed out severally in addition.

in any other position which would be of such universal efficacy as that made over this river.

In proportion as the water is more turbid it is heavier, and as it is heavier it is the swifter in its descent, and that substance which is swifter makes more impression upon its object.

They will approach by night if they are suspicious of . . .

An armed force cannot prevail against these if it is not united, and if it is united it can only be in one particular place, and being thus united in one particular place it is either weaker or stronger than the enemy; and if it be weaker and this be discerned by the enemy by means of its spies they will pass by treachery . . .

(I having) my most illustrious lords (examined closely the river of the Isonzo) having the conditions (and in addition to this having been informed) by the country-folk (I have been informed) how from whatever side (the country-folk) the enemy may arrive.

My most illustrious Lords—As I have carefully examined the conditions of the river Isonzo, and have been given to understand by the country-folk that whatever route on the mainland the Turks may take in order to approach this part of Italy they must finally arrive at this river, I have therefore formed the opinion that even though it may not be possible to make such defences upon this river as would not ultimately be ruined and destroyed by its floods . . .

My most illustrious Lords—As I have (well considered the conditions of the river) recognised that by whatever side of the mainland the Turks may think to approach our Italian lands they must needs finally arrive at them by the river Isonzo . . .

OF CHANGING THE POSITION OF THE RIVER

Of what may be said against its permanence, and what the logs which are brought by the rivers will break.

To this I reply that all the supports should be equal in height with the lowest depth of the banks; so if the river should come to rise to this height it will not enter in the woods near to the bank, and not entering there it will not be possible for it to carry away any logs, and so the river will flow with only its own water in mere turbulence.

And if it rises above its bank, as has been seen this year when it rose about four braccia above the lower bank, it carries very great logs with it, bearing them floating along accompanying its course, and then leaves them resting firmly fixed against the larger trees which are of such a kind as to offer resistance, and they remain caught in the branches.

If however they are borne along on the river it is because they have few or no branches and float on the surface and do not touch the toothed barrier which I have set up.

When the great floods come which carry logs and very large trees they will pass four or five braccia above the tops of these defences, and the signs of this are seen by the objects left fixed to the branches of the trees when it has risen.

When the water has no current it will easily and speedily become choked up with faggots, for those which have fallen into it will be always turning back . . .[1] C.A. 234 V. C

So greatly did I rejoice, most illustrious Lord, at your much wished-for restoration to health that I found my own malady had almost left me at the news of your Excellency's recovery. But I am extremely sorry that I have not been able entirely to satisfy your Excellency's desires, through the malice of this rogue, as regards whom I have never omitted to do anything which I possibly could which might be of service to him. In the first place, his salary was always paid him before it was due,

[1] I have ventured to change the order of a few of the sentences of this letter as they occur in the edition published by the Accademia dei Lincei, in the attempt to enhance the sense of continuity.

On the same page is a slightly drawn sketch or plan of road and river communications with the words *ponte di goritia* (bridge of Gorizia) and *vil pagho alta alta.* The last word refers presumably to the nature of the land, the first is identical with Wippach (Italian Vipacco), the name of an eastern tributary of the Isonzo and also of a village under which it flows, which lies on a spur of the hills some twenty kilometres west of Gorizia. From the position of Wippach it would seem to dominate the road across the mountains from Laibach to Gorizia, which would be the probable route that would be taken by an army advancing from the east to cross the Isonzo at Gorizia. Wippach lies some four kilometres to the south of this road and is connected with it by two roads running north-east and north-west.

which I believe he would gladly deny if it were not that I had the signature witnessed by the hand of the interpreter. And as I saw that he would not work for me unless he could not find any work to do for others, and that he sought for this diligently, I urged him to have his meals with me and to work with his files near to me, for besides this being economical and good for his work it would help him to acquire Italian; and so he always promised to do but he was never willing to do it. He acted in this way because that German Giovanni who makes mirrors was every day in his workshop, and wanted to see and understand all that was being done and then talked about it everywhere, finding fault with what he did not understand. And also because he went to dine with the men of the Pope's guard, and then went out with them with guns to kill birds in the ruins, and pursued this course from dinner-time until the evening. And if I sent Lorenzo to him to urge him to work he got in a rage with him, and told him that he wasn't going to have so many masters over him, and that he was at work upon your Excellency's Wardrobe. So two months passed and the thing still went on, until one day happening to find Gian Niccolò of the Wardrobe I asked him whether the German had finished his work for Il Magnifico, and he told me that it was none of it true because he had only given him two guns to clean. After this when I expostulated with him he left the workshop and began to work in his own room, and wasted a lot of time in making another vice and files and other instruments with screws, and made shuttles there to twist silk and gold, which he hid whenever any of my people went in, and this with a thousand oaths and revilings, so that none of them were willing to go there any more.

So greatly did I rejoice, most illustrious Lord, at your much wished-for restoration to health that my own malady almost left me. But I greatly regret that I have been unable to satisfy the desires of your Excellency, entirely through the malice of that German rogue, as regards whom I have left nothing undone which I thought might give him pleasure. And firstly because I invited him to take up his abode and have meals with me, so that I could always see what work he was doing and could easily correct his errors, and moreover he would acquire Italian and so be able to speak it easily without an interpreter, and most important of all the moneys due to him could always be paid before the time, as always has been. Then he asked that he might have the models finished in wood just as they were to be in iron, and wished to carry them away to his own country. But this I refused, telling him that I would give him a drawing of the width, length, thickness and outline of what he had to, and so we remained at enmity.

The second thing was that in the room where he slept he made himself another workshop with new screw-vices and instruments, and there worked for others. Afterwards he went to dine with the Swiss of the Guard where there are plenty of idlers, but he beat them all at it. Then he used to go out and more often than not two or three of them went together with guns to shoot birds among the ruins, and this went on until the evening.

Finally I discovered that it was this master Giovanni who made mirrors who had brought all this about and this for two reasons; first because he had said that my coming here had deprived him of the countenance and favour of your Lordship which always..., and the other reason is because he says the room of this iron-worker would suit him for working at mirrors, and he has given proof of this, for besides setting him against me he has made him sell all his effects and leave his workshop to him, and he has established himself there now with a number of assistants making many mirrors to send to the fairs.

C.A. 247 v. b

My Lords, Fathers, Deputies,—Just as for the doctors, the tutors and guardians of the sick, it is necessary that they should understand what man is, what life is, and what health is, and how a parity or harmony of elements maintains this, and in like manner a discord of these ruins and destroys it; and anyone who has acquired a good knowledge of these conditions will be better able to effect cures than one who is without it . . .

You know that medicines when well used restore health to the sick: they will be well used when the doctor together with his understanding of their nature shall understand also what man is, what life is, and what constitution and health are. Know these well and you will know their opposites; and when this is the case you will know well how to devise a remedy—

You know that medicines when well used restore health to the sick, and he who knows them well will use them well when he also knows what man is, and what life and the constitution are, and what health is. Knowing these well he will know their opposites, and being thus equipped he will be nearer to devising a remedy than anyone else. In just the same way a cathedral in need of repair requires a doctor-architect who understands well what a building is, and on what rules the correct method of construction is based, and from whence these rules are derived, and into how many parts they are divided, and what are the causes which hold the structure together, and make it permanent, and what the nature of weight is and what the desire of strength, and how these should be interwoven and bound up together, and what effect their union produces. Whoever shall have a true knowledge about the above-named things will satisfy you both by his intelligence and his work.

So for this reason I shall endeavour without disparaging and without defaming anyone to satisfy you partly by arguments and partly by demonstration, sometimes revealing the effects from the causes, sometimes confirming the reasoning from experience, fitting with them certain of the principles of the architects of old time and the evidence of the buildings they constructed and [showing] what were the reasons of their destruction or their permanence.

And I shall show at the same time what is the first [law] of weight, and what and how many are the causes which bring ruin to buildings, and what is the condition of their stability and permanence.

But in order not to be diffuse to your Excellencies I will speak first of the invention of the first architect of the cathedral, and will show you clearly what was his purpose, confirming this by the building which has been commenced, and when I have made you understand this you will be able clearly to recognise that the model which I have constructed possesses in itself that symmetry, that harmony, and that regularity which belongs to the building already begun.

What a building is, and where the rules of sound construction derive their origin, and what and how many are the parts that belong to these. . . .

Either I or some other who may expound it better than I, choose him, and set aside all partiality. C.A. 270 r. c

Though the marble should be delayed for ten years I do not wish to wait for my payment beyond the term of the end of my work.

C.A. 277 v. a

So greatly did I rejoice, most illustrious Lord, at your much wished for restoration to health that my own malady almost left me, for which God be praised. But I am extremely sorry that I have not been able entirely to satisfy your Excellency's desires, through the malice of this German rogue, as regards whom I have left nothing undone which I thought would give him pleasure.

And in the first place his money was always paid in full before the date of the month at which his salary was due; secondly I invited him to lodge and board with me; for which purpose I was prepared to set up a table at the foot of one of these windows, where he could work with his file and finish the things he had made below; and by this means I should always see the work that he did and it could be corrected with ease. And besides this he would learn the Italian language and so be able to speak it easily without an interpreter. C.A. 283 r. a

[*Fragments of a letter to Ludovic Sforza*]

I do not regret so much my being. . . .

I regret very much my being in want, but I mourn for it the more because it has been the means of preventing me from carrying out my desire, which has always been to obey your Excellency.

I regret very much that you should have requisitioned me and found me in want, and that the fact of my having to gain my living should have hindered me.

I regret very much that the fact of my having to gain my living should have prevented me from continuing the work which your Highness has entrusted to me: but I hope that within a short time I shall have earned so much as to be able with a tranquil mind to satisfy your Excellency, to whom I commend myself. If your Highness thought that I had money, you were deceived, for I have had six mouths to feed for thirty-six months, and I have had fifty ducats.

It may be that your Excellency did not give any further orders to Messer Gualtieri, believing that I had money. C.A. 315 v. a

I suspect that the poor return I have made for the great benefits that I have received from your Excellency, may have made you somewhat indignant with me, and thus it is that I have written so many letters to your Lordship and have never had a reply. I now send Salai to you, to explain to your Lordship that I am almost at the end of the lawsuit that I have had with my brothers, and that I expect to find myself with you this Easter, and to bring with me two pictures of the Madonna, of different sizes, which have been made either for our Most Christian King, or for whomsoever your Lordship pleases. I should be very glad to know on my return there where I am to take up my abode, as I would not give any more trouble to your Lordship; and also, as I have been working for the Most Christian King, whether my salary is to continue or not.

I am writing to the President about that water which the King granted me, and of which I was not given the possession, because at that time there was a shortage in the canal by reason of the great drought, and because its outlets were not being regulated; but he gave me a definite promise that when this was done I should be put in possession, so that I beseech your Lordship not to be unwilling now that the outlets are regulated to remind the President of my suit, namely that I should be given possession of this water, for when I am established there I look forward to constructing machines and devices which should be a source of great pleasure to our Most Christian King. Nothing else occurs to me. I am always at your commands. C.A. 317 r. b

Piacenza is a place of resort like Florence.

Illustrious Commissioners of Buildings! hearing that your Excellencies have resolved upon the construction of certain great works in bronze, I propose to offer you certain counsels on the subject. First then take care not to act so swiftly and hastily in awarding the commission that by your speed you put it out of your power to make a good choice both of subject and of a master, as Italy has a number of men of capacity. Some fellow, that is, who by his incompetence may afterwards afford occasion to your successors to cast blame on yourselves and your generation, judging that this age was poorly equipped either with men of good judgment or good masters, seeing that other cities and especially the city of the Florentines were almost at this very same time enriched with such beautiful and great works in bronze, amongst these being the gates of their baptistery. Florence indeed, like Piacenza, is a place of resort, where many visitors congregate, and these when they see its beautiful and stately works of art form the impression that the city must have worthy inhabitants, seeing that these works serve as evidence of this; but they form quite a different impression if they see a great expenditure in metal wrought so poorly that it would be less of a reproach to the city if the doors were of plain wood, for then the material would have cost little and therefore would not seem to require a great degree of skill.

Now, the parts principally sought for in cities are their cathedrals, and, as one approaches these, the first objects which meet the eye are their doors by which one enters into the churches.

Beware, gentlemen of the Commission, lest the too great speed, whereby you desire, with such swiftness as I perceive you use, to allot the commission for so important a work, may become the reason why what was intended for the honour of God and of men may prove a great dishonour to your judgment and to your city, where as it is a place of distinction and of resort there is an innumerable concourse of visitors. This disgrace would befall you if by your negligence you put your trust in some braggart who, by his subterfuges or by the favour here shown him, were to be awarded such a commission by you as should bring great and lasting shame both to him and to you.

I cannot help feeling angry when I reflect upon the sort of men who have made me a confidant of their desire to embark upon such an undertaking, without giving a thought to their capacity for it—not to say more.

One is a maker of pots, another of cuirasses, a third makes bells and another collars for them, another even is a bombardier; yet another is in the Duke's household and boasts that he is by way of being an intimate acquaintance of Messer Ambrogio Ferrere, and that he has some influence and has made certain promises to him, and if this does not satisfy you he will get on his horse and ride off to the Duke, and will get such letters from him that you will never be able to refuse him the work.

But consider to what straits the poor masters who by study have made themselves competent to execute such works are reduced, when they have to contend against fellows like these! What hope have they of being able to look for reward for their talent!

Open your eyes and try to ensure that your money is not so spent as to purchase your own shame. I can assure you that from this district you will get nothing except the works of hard, mean, or clumsy masters. There is not a man who is capable—and you may believe me—except Leonardo the Florentine who is making the bronze horse of the Duke Francesco; and you can leave him out of your calculations altogether, for he has a work to do which will last him the whole of his life, and indeed I doubt whether he will ever finish it, so great it is.

C.A. 323 r. b

Here is one whom the Lord has invited from Florence to do this work for him and he is a capable master, but he has so much, oh! so much, to do that he will never finish it.

What do you imagine is the difference between seeing a beautiful object and an ugly one? Quote Pliny. C.A. 323 v. b

[*Fragment of letter to Ludovic Sforza*] (*MS. Sheet torn vertically*)

And if you give me some further commission for any [. . .]
for the reward of my service for I am unable to [. . .]
certain drafts because they have revenues from [. . .]
who can adjust them properly more than I can [. . .]
not my art which I wish to change and [. . .]
given some clothing.

My Lord, knowing the mind of your Excellency to be occupied [. . .]
to remind your Lordship of my small matters, and I should have maintained silence [. . .]
that my silence should be the cause of making your Lordship become angry [. . .]
my life to your service I hold myself ever ready to obey [. . .]
Of the horse I will say nothing because I know the times [. . .]
to your Lordship how my salary is now two years in arrear of [. . .]

with two masters whose salaries and board I have always
paid [. . .]
that at last I found that I had advanced the said work
about fifteen lire [. . .]
works of fame by which I could show to those who are to
come that I have been [. . .]
does everywhere; but I do not know where I could spend
my work in order to [. . .]
I have been occupied with gaining a living
Through not being informed in what condition I find
myself as it [. . .]
you remember the commission to paint the Camerini [. . .]
I conveyed to your Lordship only requesting from you [. . .]

C.A. 335 v. a

Amid the whirling currents of the winds were seen a great number of companies of birds coming from distant lands, and these appeared in such a way as to be almost indistinguishable, for in their wheeling movements at one time all the birds of one company were seen edgewise, that is showing as little as possible of their bodies, and at another time showing the whole measure of their breadth, that is full in face; and at the time of their first appearance they took the form of an indistinguishable cloud, and then the second and third bands became by degrees more clearly defined as they approached nearer to the eye of the beholder.

And the nearest of the above-mentioned bands dropped down low with a slanting movement, and settled upon the dead bodies, which were borne along by the waves of this great deluge, and fed upon them, and so continued until such time as the buoyancy of the inflated dead bodies came to fail, and with slow descent they sank gradually down to the bottom of the waters.[1] C.A. 354 v. b

Illustrious President, I am sending Salai, my pupil, to you as the bearer of this, and you will learn from his own mouth the reason of my great . . .

Illustrious President,—Having often remembered the promises made to me by your Excellency, I have several times thought of insuring

[1] See Note on page 1139.

myself by writing and reminding you of the promise made to me at my last departure, namely as to the possession of those twelve ounces of water granted to me by the Most Christian King. Your Lordship knows that I did not enter into possession of it, because at the time when it was granted to me there was a dearth of water in the canal, partly on account of the great drought and partly because the outlets had not yet been regulated. But your Excellency promised me that when this had taken place I should have my expectations fulfilled. Consequently when I was given to understand that the canal had been regulated I wrote several times to your Lordship and to Messer Girolamo da Cusano who has the deed of gift in his keeping, and I wrote also to Corigero, but have never had any reply.

I am now sending to you as bearer of this [letter] Salai, my pupil, to whom your Lordship will be able to tell by word of mouth all that has occurred as regards the matter in which I am petitioning your Excellency.

I expect to be with you this Easter as I am almost at the end of my lawsuit, and I shall bring with me two Madonna pictures which I have begun, and which considering the time at my disposal I have brought to a very fair state of completion. Nothing else occurs to me. . . .

My Illustrious Lord [Antonio Maria], the affection which your Excellency has always shown to me and the benefits which I have received from you are continually in my thoughts.

I have a suspicion that the small response I have made for the great benefits which I have received from your Excellency may have made you somewhat incensed with me; and that this is the reason why I have never had any reply to the many letters that I have written to your Excellency. I am now sending Salai to you to explain to your Lordship that I am almost at the end of my litigation with my brothers, and that I hope to be with you this Easter, and to bring with me two pictures of the Madonna of different sizes, which I have begun for the Most Christian King or for whomsoever else it shall please you. I shall be very glad to know on my return there where I am to have my lodging, because I would not wish to give any more trouble to your Lordship, and further whether seeing that I have been engaged in work for the Most Christian King my salary is to continue or not. I am writing to the President of that water which the king granted me, of which I was not given possession on account of the scarcity in the canal due to the great drought, and to the fact of the outlets not having been regulated; he promised me however that as soon as this was done I should be put in possession; so that I beseech you if you should happen to meet the said President not to think it irksome, now that these outlets are regulated, to remind him to have me put in possession of this water, since I am given to understand that in great measure it rests with him. Nothing else occurs to me. I am always at your commands.

Good day to you, Messer Francesco, God knows why when I have written you so many letters you have never made me a single reply. Just wait until I come to you, by God, for I will make you write so much that you will perhaps be sorry for it.

Dear Messer Francesco, I am sending Salai to you in order to learn from his Excellency the President what conclusion has been reached in the matter of the regulation of the water, since at my departure the order for the outlets of the canal had been set in hand; because the illustrious President promised me that my claim should be settled so soon as ever this adjustment had been made. It is now a considerable time since I learnt that the canal was set in working order and likewise its outlets, and I wrote immediately to the President and to you, and then repeated my letters, but have never had any reply. Will you therefore have the kindness to write and inform me what has taken place, and unless it is actually on the point of settlement, will you for my sake be so kind as to exert a little pressure on the President and also on Messer Girolamo da Cusano, to whom please commend me, and also offer my respects to his Excellency? C.A. 372 v. a

I have one who having promised himself things from me which were not at all what he deserved, and being baulked of his presumptuous desire has tried to turn all my friends from me. And because he has found them wise and not pliant to his will, he has threatened me that he will spread such a report[1] about me as will deprive me of my benefactors. For this reason I have informed your Lordship of this, so

[1] *relazione*, (MS., . . . *zione*).

that when this fellow attempts to sow the usual scandals he may find no ground suitable for sowing to receive the thoughts and acts of his evil nature. Consequently if he should try to make your Lordship the instrument of his wicked and malicious nature he may be left baulked of his desire. C.A. 389 v. d

[*Draft of letter to Ludovic Sforza,* 1482 (*circa*)]

Most Illustrious Lord, having now sufficiently seen and considered the proofs of all those who count themselves masters and inventors of instruments of war, and finding that their invention and use of the said instruments does not differ in any respect from those in common practice, I am emboldened without prejudice to anyone else to put myself in communication with your Excellency, in order to acquaint you with my secrets, thereafter offering myself at your pleasure effectually to demonstrate at any convenient time all those matters which are in part briefly recorded below.

1. I have plans for bridges, very light and strong and suitable for carrying very easily, with which to pursue and at times defeat the enemy; and others solid and indestructible by fire or assault, easy and convenient to carry away and place in position. And plans for burning and destroying those of the enemy.

2. When a place is besieged I know how to cut off water from the trenches, and how to construct an infinite number of bridges, mantlets, scaling ladders and other instruments which have to do with the same enterprise.

3. Also if a place cannot be reduced by the method of bombardment, either through the height of its glacis or the strength of its position, I have plans for destroying every fortress or other stronghold unless it has been founded upon rock.

4. I have also plans for making cannon, very convenient and easy of transport, with which to hurl small stones in the manner almost of hail, causing great terror to the enemy from their smoke, and great loss and confusion.

9. And if it should happen that the engagement was at sea, I have plans for constructing many engines most suitable either for attack or defence, and ships which can resist the fire of all the heaviest cannon, and powder and smoke.

5. Also I have ways of arriving at a certain fixed spot by caverns and secret winding passages, made without any noise even though it may be necessary to pass underneath trenches or a river.

6. Also I can make armoured cars,[1] safe and unassailable, which will enter the serried ranks of the enemy with their artillery, and there is no company of men at arms so great that they will not break it. And behind these the infantry will be able to follow quite unharmed and without any opposition.

7. Also, if need shall arise, I can make cannon, mortars, and light ordnance, of very beautiful and useful shapes, quite different from those in common use.

8. Where it is not possible to employ cannon, I can supply catapults, mangonels, *trabocchi* and other engines of wonderful efficacy not in general use. In short, as the variety of circumstances shall necessitate, I can supply an infinite number of different engines of attack and defence.

10. In time of peace I believe that I can give you as complete satisfaction as anyone else in architecture in the construction of buildings both public and private, and in conducting water from one place to another.

Also I can execute sculpture in marble, bronze or clay, and also painting, in which my work will stand comparison with that of anyone else whoever he may be.

Moreover, I would undertake the work of the bronze horse, which shall endue with immortal glory and eternal honour the auspicious memory of the Prince your father and of the illustrious house of Sforza.

And if any of the aforesaid things should seem impossible or impracticable to anyone, I offer myself as ready to make trial of them in your park or in whatever place shall please your Excellency, to whom I commend myself with all possible humility. C.A. 391 r. a

[*Fragment of letter*]

All the evils that exist or that ever have existed set in train by this man would not satisfy the desire of his malignant spirit.

[1] MS., *carri coperti.*

No length of time would suffice me to unfold this man's nature to you, but I am fully convinced that . . . H 137 [6 v.] r.

To release my salary, not to give out the works in a block, but to bring about that the chief official be he who by the use of my instruments curtails all the superfluous and cumbersome inventions of those of whom one makes use. L 91 r.

To my most illustrious Lord, Ludovic,
Duke of Bari,
Leonardo da Vinci, Florentine,
Leonardo . . .[1] Forster III 62 v.

May it please you to look at a model[2] which may be of advantage both to you and to me and its usefulness may extend to those who will be the cause of our usefulness. Forster III 68 r.

Most Illustrious, most Reverend, and my Unique Lord, The Lord Ippolito, Cardinal of Este, My Supreme Lord, at Ferrara.

Most Illustrious and Most Reverend Lord,

A few days ago I arrived from Milan, and finding that one of my elder brothers refuses to carry out the provisions of a will made three years ago when our father died: as also no less because I would not seem to myself to fail in a matter that I consider most urgent, I cannot forbear to request of your most Reverend Highness a letter of commendation and favour to Ser Raphaello Hieronymo, who is now one of the members of our illustrious Signoria before whom my case is being tried; and more particularly it has been referred by his Excellency the Gonfaloniere to the said Ser Raphaello, so that his Lordship may be able to reach a decision and bring it to completion before the coming of the festival of All Saints.

And therefore, my Lord, I beseech you, as earnestly as I know how and am able, that your Highness will write a letter to the said Ser Raphaello in that happy and engaging manner that you have the art

[1] Opening words of letter written presumably before September 1494 at which date Ludovic was proclaimed Duke of Milan.

[2] The model here referred to may be that of the equestrian statue exhibited in Milan on the occasion of the marriage of the Emperor Maximilian with Bianca Maria Sforza in the year 1493.

of, commending to him Leonardo Vincio, your most humble servant, as I call myself and always wish to be; requesting and urging that he may be desirous not only to do me justice but to do so with kindly urgency; and I have no doubt at all from many reports that have reached me that inasmuch as Ser Raphaello is most kindly disposed to your Highness the matter will then proceed *ad votum*. And this I shall attribute to the letter of your most Reverend Highness, to whom once more I commend myself.[1] *Et bene valeat.*

Florence 18 September 1507.

E.V.R.D.

Your most humble servant,
Leonardus Vincius, *pictor*.

[1] Text in Marchese G. Campori: Nuovi Documenti per la Vita di Leonardo da Vinci. 'Atti e Memorie della R. Deputazione di storia patria di Modena,' 1865.

XLVIII

Dated Notes

'This winter of the year 1510 *I look to finish all this anatomy.'*

ON THE second day of April 1489 the book entitled 'Of the Human Figure'. Fogli B 42 r.

In eighty-nine [the year 1489] there was an earthquake in the sea of Satalia near to Rhodes. Leic. 10 v.

On the twenty-third day of April 1490 I commenced this book and recommenced the horse. C 15 v.

On the last day but one of February.

Thursday on the twenty-seventh of September.

The master Tommaso has returned, he has worked for himself down to the last day but one of February.

On the eighteenth day of March 1493 Giulio the German came to live with me.

Antonio, Bartolomeo, Lucia, Piero, Lionardo.

On the sixth day of October. Forster III 88 v.

On the sixteenth day of July.

Caterina [1] came on the sixteenth day of July 1493. Forster III 88 r.

1493.

On the first day of November we made up our accounts. Giulio had to pay for four months and the master Tommaso for nine. The master

[1] Caterina was the name of his housekeeper. See note as to household accounts of 29 January 1494 (p. 1157). There is a note in Forster MS. II as to the expenses of Caterina's burial: (see p. 1129) Caterina was the name of Leonardo's mother and conjecture may feed upon these facts.

Tommaso afterwards made six candlesticks: ten days. Giulio some fire-tongs: fifteen days. Then Giulio worked for himself up to the twenty-seventh of May, and worked for me at a lifting-jack until the eighteenth day of July, afterwards for himself until the seventh day of August, and in this month, a day for a lady, then for me for two locks until the twentieth day of August. H 106 [37 r.] v.

[*Accounts*]

On the twenty ninth day of January 1494.

Cloth for hose	four lire of five soldi
Lining	sixteen soldi
Making	eight soldi
Salai	eight soldi
Ring of jasper	thirteen soldi
Sparkling stone	eleven soldi
Caterina	ten soldi
Caterina	ten soldi

H 64 [16] v.

On the 2nd day of February 1494 at the Sforzesca I have drawn twenty-five steps each of two thirds of a braccio and eight braccia wide.
H 65 [17] v.

On the twenty-fifth day of August twelve lire from Polyxena.

On the fourteenth day of March 1494 Galeazzo came to live with me, agreeing to pay five lire a month for his keep, paying on the fifteenth day of each month.

His father gave me two Rhenish florins.

On the fourteenth day of July I had two Rhenish florins from Galeazzo. H 41 r.

Vineyards of Vigevano. On the 20th day of March 1494. And in the winter they are covered with earth. H 38 r.

On the fifth day of September 1494 Giulio began the lock of my small study. H 105 [38 v.] r.

To-morrow morning on the second day of January 1496 I will make the thong and the attempt. C.A. 314 r. b

[*Salaino expenses* 1497]

The cloak of Salai the fourth day of April 1497

4 braccia of silver cloth	15 lire	4 soldi
green velvet for the trimming	9 lire	
ribbons		9 soldi
small rings		12 soldi
for the making	1 lira	5 soldi
ribbon for the front		5 soldi
stitching		
here for his grossoni[1] 13	(26 lire	5 soldi)

[*In chalk*] Salai stole the soldi. L 94 r.

Monday I bought forty-six braccia of cloth, thirteen lire, fourteen and a half soldi, on the seventeenth day of October 1497. I 49 [1] v.

On the first day of August 1499 I wrote here of movement and weight. C.A. 104 r. b

Dovecot at Urbino. 30 July 1402 (1502) L 6 r.

First day of August 1502.
At Pesaro, the Library. L cover r.

Make a harmony with the different falls of water as you have seen at the fountain of Rimini, as you have seen on the eighth day of August 1502. L 78 r.

St. Mary's Day, the middle of August, at Cesena, 1502. L 36 v.

Porto Cesenatico on the sixth day of September 1502 at fifteen hours.

How bastions ought to project beyond the walls of towns to be able to defend the outer slopes so that they may not be struck by the artillery. L 66 v.

Memorandum how on the eighth day of April 1503 I Lionardo[2] da Vinci lent Vante [Attavante] the miniaturist four gold ducats in gold. Salai took them to him and gave them into his own hand. He undertook to repay me within forty days.

Memorandum how on the above-mentioned day I gave Salai three

[1] Grossone—an old Tuscan coin—value about 30 centesimi (Fanfani).
[2] Leonardo, like Shakespeare, spelt his name in more than one way.

gold ducats which he said he needed, in order to get a pair of rose-coloured stockings with their adornments.

And I have still to give him nine ducats, against which he owes me twenty ducats, that is seventeen lent at Milan and three at Venice.

Memorandum how I gave Salai twenty-one braccia of cloth for making shirts, at ten soldi the braccio: which I gave him on the twentieth day of April 1503. B.M. 229 V.

On the morning of St. Peter's Day, on the twenty-ninth day of June 1504, I took ten ducats, of which I gave one to Tommaso my servant to spend. C.A. 71 V. b

On the ninth day of July 1504, on Wednesday at seven o'clock, died, at the Palace of the Podestà, Ser Piero da Vinci, notary, my father, at seven o'clock; he was eighty years old, he left ten sons and two daughters. B.M. 272 r.

On Wednesday, at seven o'clock, died Ser Piero da Vinci, on the ninth day of July 1504.

On Friday the ninth day of August 1504 I took ten ducats from the cupboard. C.A. 71 V. b

1504

On Friday the ninth day of August 1504 I drew ten gold florins.

On the morning of Saturday the third day of August 1504 Jacopo the German came to stay with me in my house; he arranged with me that I should allow him a carline a day for his expenses.

Have given Friday the ninth day of August fifteen grossoni, that is five florins five soldi.

Has given me one gold florin on the twelfth day of August.

Have given on the fourteenth day of August three grossoni to Tommaso.

And on the eighteenth day of the said [month] five grossoni to Salai.

On the eighth day of September six grossoni to the steward to spend, that is the day of Our Lady.

On the sixteenth day of the said September four grossoni to Tommaso, on Sunday. B.M. 271 V.

The *cortona* a bird of prey . . . I saw going to Fiesole above the place of the Barbiga in 5 (the year 1505) on the fourteenth day of March.
Sul Volo (F.M.) 18 [17] v.

1505, on the evening of Tuesday the fourteenth day of April Lorenzo came to live with me; he said that he was seventeen years of age.

And on the fifteenth day of this April I had twenty-five gold florins from the Treasurer of Santa Maria Nuova. Sul Volo 18 v.

Book entitled 'Of Transformation', that is of one body into another without diminution or increase of substance. Forster I 3 r.

Begun by me, Leonardo da Vinci, on the twelfth day of July 1505.
Forster I 3 v.

Begun at Florence in the house of Piero di Braccio Martelli, on the 22nd day of March, 1508.[1] B.M. I r.

Begun at Milan on the 12th day of September 1508. F I r.

On a day of October 1508 I had thirty crowns. I lent thirteen to Salai to complete his sister's dowry, and I have seventeen remaining.
F cover 2 r.

[*Of Squaring the Circle*]

1509, April 28

Having for a long time sought to square the angle of two curved sides, that is the angle *e*, which has two curved sides of equal curve, that is curve created by the same circle: now in the year 1509, on the eve of the calends of May, I have solved the proposition at ten o'clock on the evening of Sunday. I know therefore (as is shown on the reverse of this page *A*) that the surface *a b* taken from its position and given the same value with the portion *c* as the rectilinear triangle *d c* corresponds exactly to the curvilinear triangle *e c*, I would call it the curvilinear triangle *a b d*. Therefore that square of the triangle *e* will be found in the rectilinear triangle *c d*.

Windsor MSS. (Beltrami: *Documenti e memorie*, 201)

[1] Opening words of Manuscript (see Page 41).

[*With drawing, washed with green and sepia, of sluices showing water flowing through the outlets*]

Canal of San Cristoforo at Milan made on the third day of May 1509. C.A. 395 r. a

1510. On the twenty-sixth day of September Antonio broke his leg. He must not move for forty days. G cover r.

This winter of the year 1510 I look to finish all this anatomy. Fogli A 17 r.

Monbracco above Saluzzo, a mile above the Certosa, at the foot of Monte Viso, has a mine of stratified stone, white as marble of Carrara and flawless, and hard as porphyry or even harder. My gossip the master Benedetto the sculptor has promised to send me a tablet for the colours; on the fifth day of January 1511. G I v.

On the tenth day of December at nine o'clock in the morning the place was set on fire.

On the eighteenth of December 1511, at nine o'clock in the morning, this second conflagration was started by the Swiss at Milan, at the place called DCXC. Windsor: Drawings 12416

[*Sketch-Plan. 'Room of the tower of Vaneri'*]

On the ninth day of January 1513. Quaderni II 7

I departed from Milan for Rome on the 24th day of September, 1513, with Giovanni, Francesco de' Melzi, Salai, Lorenzo and il Fanfoia. E I r.

[*With drawings of segments of circles and mathematical calculations*]

Finished on the seventh day of July, at the twenty-third hour, in the Belvedere, in the study given to me by the Magnifico, 1514. C.A. 90 v. a

At the Bell at Parma, on the twenty-fifth day of September, 1514.[1] E 80 r.

[1] I have followed Richter in interpreting the words *alla campana* as having reference to an Inn. Ravaisson-Mollien thinks that *campana* may perhaps be a variant of *campagna,* and translates *A Parme, à la campagne.* In a passage in the Leicester MS., written,

Il Magnifico Giuliano de' Medici set out on the ninth day of January 1515 at daybreak from Rome, to go and marry a wife in Savoy.

And on that day came the news of the death of the King of France.[1]

G cover v.

DIMENSIONS

San Paolo at Rome has five naves and eight columns, and its width inside its naves is 130 braccia, and from the steps of the high altar to the gate 155 braccia, and from these steps to the end wall behind the high altar 70 braccia, and the porch is 130 braccia long and 17 braccia wide.

Made on the . . . day of August, 1516. C.A. 172 v. b

Ascension Day at Amboise, in Cloux, May 1517. C.A. 103 r. b

On the twenty-fourth of June, the day of St. John, 1518, at Amboise, in the palace of Cloux. C.A. 249 r. a

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according to Calvi, between 1504 and 1506, Leonardo refers to the multitude of shells and corals sticking to the rocks which are to be seen in the mountains of Parma and Piacenza. The passage has the air of being based on first-hand knowledge. If the suggestion *campagna* be accepted it might be that Leonardo was revisiting some of his old haunts. The text, however, really only establishes his presence at Parma on the date mentioned. As such, it proves that his stay in Rome was interrupted. Dated references attest his presence there on the seventh of July 1514, and as late as August 1516. The visit to Parma may possibly have been connected with the fact that Parma was one of the papal cities of which Giuliano de' Medici, Leonardo's patron in Rome, had been made the governor.

[1] Louis XII died on the first of January 1515.

XLIX

Books

'In youth acquire that which may requite you for the deprivations of old age; and if you are mindful that old age has wisdom for its food, you will so exert yourself in youth, that your old age will not lack sustenance.'

SEE Aristotle 'De Coelo' and 'De Mundo'. C.A. 97 v. a

[*References to books from a list of memoranda*]

Book of Pandolfino.
Library of San Marco.
Library of Santo Spirito.
Lactantius of the Daldi.
Book of Maestro Palago the hospital superintendent.
Grammar of Lorenzo de' Medici.
Book of Maso.
Learn multiplication from the root from Maestro Luca.
My map of the world which Giovanni Benci has.
Map of the world of Giovanni Benci.
Country round about Milan in a print. C.A. 120 r. d

Book of Arithmetic
Pliny
Bible
De Re Militari
First Decade
Third Decade
Fourth Decade
Guido
Piero Crescentio
Il Quadriregio
Donatus
Justinus
Guido
Dottrinale
Morgante
John de Mandeville
De Onesta Voluttà
Manganello

Cronica Desidero
Letters of Ovid
Letters of Filelfo
The Sphere
The Jests of Poggio
Of Chiromancy
Formulary of Letters
Fiore di Virtù
Lives of the Philosophers
Lapidary
Letters of Filelfo
On the Preservation of the Health
Ciecho d' Ascoli
Albertus Magnus
Rhetorica Nova
Cibaldone
Æsop
Psalms
On the Immortality of the Soul
Burchiello
Il Driadeo
Petrarch C.A. 210 r. a

BIBLIOGRAPHICAL NOTES

The existence of this list of books on a page of the Codice Atlantico affords fair ground for the supposition that Leonardo was enumerating the books which he possessed.

Marchese Girolamo d'Adda, from whose erudition as displayed in a rare tract—*Leonardo da Vinci e la sua Libreria—note di un Bibliofilo*, Milano 1873—the notes that follow are mainly derived, has suggested that as Leonardo uses the Italian and not the classical form of the names of classical authors he may be supposed to be referring to Italian translations. I cannot think that this inference necessarily holds, any more than it would in the case of a modern writer who might use the forms Virgil and Horace in a list of books. There were, however, in existence Italian translations of all the classical works mentioned, and any of these may have been in Leonardo's possession. D'Adda's wealth of bibliographical knowledge causes his descriptions of the various works in the list to serve as an 'open sesame' to Leonardo's library. The notes that follow fall by contrast under the censure that Leonardo invoked on those who make epitomes:—

BOOK OF ARITHMETIC—Perhaps La nobel opera de arithmetica ne la qual se tracta tutte cosse a mercantia pertinente facta per Piero Borgi da Veniesia. Venice 1484. The name Maestro Piero dal Borgo occurs in Arundel MS. (B.M.) fol. 190 v. (see p. 1181). The

[*Bibliographical Notes:—continued*]

two notes that follow refer to a book, viz. 'to have my book bound' and 'show the book to Serigatto'.

PLINY—Historia naturale di C. Plinio Secondo tradocta di lingua latina in fiorentina per Christoforo Landino. 1476 Venetiis.

BIBLE—Earliest Italian version: Biblia volgare historiata. Venecia 1471.

DE RE MILITARI—Valturio? Roberti Valturii de re militari libri XII 1472. Bologna 1483.

FIRST, THIRD AND FOURTH DECADES [OF LIVY]—Earliest Italian version: Tito Livio volgarizzato. Roma 1476.

GUIDO—D'Adda suggests Guido da Cauliaco, author of treatise on surgery:—Guidonis de Cauliaco Cyrurgia. Venetiis 1498.

PIERO CRESCENTIO—writer on agriculture: Ruralium commodorum lib. XII. Petri de Crescenciis 1471. Il Libro della Agricultura di Pietro Crescentio. Florentiæ 1478.

QUADRIREGIO—the Four Realms:—Love, Satan, Vices, Virtues—poem composed in imitation of the Divina Commedia by Federico Frezzi of Foligno. Perugia 1481. Firenze, no date.

DONATUS—Ælius Donatus, author of a short Latin syntax, 'De Octo Partibus Orationis'. Many editions in 15th century.

JUSTINUS—a Roman historian who made an epitome of the general history of Trogus Pompeius.

GUIDO—Richter suggests Guido d'Arezzo:—monk—tenth century—inventor of tonic sol-fa musical system. Many Italian libraries possess MS. copies of his Micrologus De Disciplina Artis Musicæ.

DOTTRINALE—perhaps Doctrinal de Sapience by Gùy de Roye, Archbishop of Sens. Latin text 1388. French trans. Geneva 1478, and many others.

MORGANTE—Il Morgante Maggiore. Romantic epic by Luigi Pulci. Il Morgante 23 canti. Per Luca Venetiano stampatore 1481. Il Morgante Maggiore 28 canti, Firenze 1482, and many others.

[*Bibliographical Notes:—continued*]

JOHN DE MANDEVILLE—There were many editions of the Travels. Earliest are Le liure appelle Mandeuille 1480, and Tractato delle piu maravigliose cosse e piu notabili, che si trovano in le parte del mondo vedute . . . del cavaler Johanne da Mandavilla . . . Mediolani . . . 1480.

DE ONESTA VOLUTTÀ—Treatise by Il Platina (Bartolomeo Sacchi) Opusculum de obsoniis ac honesta voluptate. Rome about 1473, Venice 1475.
Trans. Platyne. De Honesta Voluptate è Valetudine. Friuli 1480, Venice 1487.

MANGANELLO [The Mangle?]—A savage satire against women in imitation of the Sixth Satire of Juvenal. Author a Milanese of the same name. Venice about 1500.

CRONICA DESIDERO—D'Adda suggests Cronica d'Isidoro: Comensa la cronica de sancto Isidoro menore, con alchune additione caciate del texto ed istorie della Bibia e del libro de Paulo Oroso . . . Ascoli 1477, Friuli 1480.

LETTERS OF OVID—Liber Epistolarum. In Monteregali 1473. Le Pistole di Ovidio tradotte in prosa. Napoli, no date. Epistole volgarizzate . . . Bressa 1489. El libro dele Epistole di Ovidio in rime volgare per messere Dominico da Monticelli toschano. Bressa 1491.

LETTERS OF FILELFO—Francesco Filelfo, Italian humanist. Philelphi epistolarum liber primus (libri XVI), about 1472. Epistolarum familiarum (libri XXXVII), Venice 1500.

THE SPHERE—D'Adda suggests a work by Gregorio Dati: Trattato della sfera, degli elementi, e del globo terrestre in ottava rima Cosenza 1478, or Spaera mundi of Joannis de Sacrobusto. Ferrara 1472.

THE JESTS OF POGGIO—Many editions in Latin and Italian from 1470.

OF CHIROMANCY—Brunet mentions:—Ex divina philosophorum academia coltecta: chyromantica scientia naturalis ad dei laudem

[*Bibliographical Notes:—continued*]

finit . . . Venetiis, about 1480. Chyromantica scientia naturalis. Padue 1484.

FORMULARY OF LETTERS—Formulario de epistole vulgare missive e responsive e altri flori de ornati parlamenti al principe Hercule d'Esti duca di Ferrara composto . . . da Bartolomio miniatore suo affectionato e fidelissimo servo. Bologna, no date. Venice 1487.

FIORE DI VIRTÙ (Flowers of Virtue)—A collection of moral tales and fables composed about 1320. Fiore di virtu che tratta di tutti i vitii humani . . . et come si deve acquistare la virtu. Venetia 1474.

LIVES OF THE PHILOSOPHERS—Perhaps El libro de la vita de philosophi ecc. by Diogene Laertio. Venetiis 1480.

LAPIDARY—Perhaps a translation of the Latin poem De Lapidibus of Marbodeus, or of the Mineralium Libri V of Albertus Magnus, 1476.

ON THE PRESERVATION OF THE HEALTH—Perhaps Arnaldus de Villanova Regimen Sanitatis, 1480, or Ugo Benzo di Siena Tractato utilissimo circa la conservatione de la sanitade. Mediolani 1481.

CIECHO D'ASCOLI—Francesco (diminutive ciecho) Stabili, burnt for heresy in 1347—author of L'Acerba, a speculative philosophical poem. 'In questo poema dice trovansi delineate le origini di molti trovati moderni, ed in particolare della circulazione del sangue.'

ALBERTUS MAGNUS—Perhaps Opus De Animalibus Romæ, 1478, or Liber secretorum de virtutibus herbarum lapidum et animalium, Bononiæ 1478, or Incomenza el libro chiamato della vita ecc. Napoli 1478.

RHETORICA NOVA—Laurencius Guilelmus de Saona:—Rhetorica Nova. Cambridge 1478. St. Albans 1480.

CIBALDONE—Opera de lexcellentissimo physico magistro Cibaldone electa fuori de libri autentici di medicina utilissima a conservarsi sano. Towards the end of the fifteenth century (Brunet).

[*Bibliographical Notes:—continued*]

ÆSOP—Fabulae de Esopo historiate. Venice 1481, 1490. Brescia 1487. Æsopi vita et fabulae, latine, cum versione italica et allegoriis Fr. Tuppi. Neapoli 1485.

PSALMS—El Psalterio de David in lingua volgare. Venetiis 1476.

ON THE IMMORTALITY OF THE SOUL—Marsilio Ficino. Theologia platonica, sive de animarum immortalitate. Florentine 1482.

BURCHIELLO—Li Sonetti del Burchiello fiorentino faceto et eloquente in dire cancione e sonetti sfogiati. Bononiæ 1475.

IL DRIADEO—Poem in ottava rima by Luca Pulci, elder brother of Luigi. Il Driadeo composto in rima octava per Lucio Pulcro. Florentiæ 1478. An edition printed in Florence in 1481 has 'Il Driadeo compilato per Luigi Pulci', and the title-page of that of 1489 has 'Il Driadeo di Luigi Pulci'. The edition printed in Venice, 1491, has 'Il Driadeo d'amore di Luca Pulci'. One that was printed in Florence towards the year 1500 has on the last page 'Qui finisce Il Driadeo compilato per Luca Pulci, Al Magnifico'.

PETRARCH—Many editions, commencing with Sonetti, Canzoni et Trionphi. Venetiis 1470.

[*Notes about books from a page of memoranda*]

The Algebra which is in the possession of the Marliani, written by their father.

A book which treats of Milan and its churches—to be had at the last stationer's on the way to Corduso.

Get Messer Fatio to show you [the book] on Proportions.

Get the Friar of the Brera to show you the 'De Ponderibus'.

On Proportions by Alchino, with annotations by Marliano from Messer Fatio.

The book by Giovanni Taverna which Messer Fatio has.

A treatise on the heavenly bodies by Aristotle translated into Italian.

Try to see Vitolone which is in the library at Pavia and treats of mathematics.

A nephew of Gian Angelo the painter has a book about water which belonged to his father. C.A. 225 r. b

The Letters of Phalaris[1] (*Pistole di Falaride*). C.A. 234 r. a

There is a complete Archimenides in the possession of the brother of Monsignor of Sant' Agosta in Rome. The latter is said to have given it to his brother who lives in Sardinia. It was formerly in the library of the duke of Urbino and was carried off from there in the time of the duke Valentino.[2] C.A. 349 v. f

Ammianus Marcellinus affirms that seven hundred thousand volumes of books were burnt in the siege of Alexandria in the time of Julius Caesar.[3] Tr. 1 a

Donatus.
Lapidarius.
Pliny.
Abacus.
Morgante. Tr. 2 a

Horace[4] has written of the velocity of the heavens.
Concave mirrors.
Books from Venice.
The author of an Italian-Latin Dictionary.
Knives from Bohemia.
Vitruvius.
Meteora.[5]

[1] Epistole di Falaride tradotte dal Latino di Fr. Accolti Aretino in volgare da Bartol. Fonzio fiorentino, 1471, is probably the edition here referred to. R. Bentley's Dissertation on Phalaris (1697) showed the letters to have been written by a sophist or rhetorician (possibly Adrianus of Tyre) several hundred years after the death of Phalaris.

[2] Caesar Borgia, Duke of Valentinois, expelled the Montefeltro dynasty from Urbino in the year 1497. The Duke Guidobaldo recovered possession at the beginning of October 1503, ten days after the sudden death of Pope Alexander VI had shattered the fabric of Caesar Borgia's kingdom.

[3] Ammianus Marcellinus: continued the history of the Empire at the point where Tacitus left off. A. M. historiarum libri qui extant XIII Rome, 1474.

[4] The reference, according to M. Ravaisson-Mollien, is probably to an Italian of this name who was secretary to Pope Nicholas V, wrote poetry and translated Homer.

[5] Meteora. An Italian translation of Aristotle's treatise is referred to in the Codice Atlantico. The translation must have been in manuscript.

Archimedes: On the centre of gravity.

Anatomy: Alessandro Benedetto.[1]

The Dante of Niccolo della Croce.

Philosophy of Aristotle.

Messer Ottaviano Pallavicino for his Vitruvius.

Go each Saturday to the hot house and you will see the nudes.

Blow out a pig's lung and see whether it increases in length and breadth, or in breadth and diminishes in length.

Albertuccio[2] and Marliano[3]: De Calculatione.

Alberto[4] De cœlo et mundo—from Fra Bernardino.

From Messer Mafeo[5]—why the Adige rises for seven years and falls for seven. F cover 1 v.

Avicenna: On liquids.

Posidonius[6] composed books about the size of the sun.

F cover 2 r.

Enquire for Vitruvius at the stationer's. F cover 2 v.

Of the increase of the Nile, a small work by Aristotle.

K 52 [3] v.

Alberto da Imola: Algebra. K 75 [27] v.

Messer Vincenzo Aliprandio who lives near the inn of the Corso has Giacomo Andrea's Vitruvius. K 109 [29-30] v.

Borges will get the Archimedes of the bishop of Padua for you, and Vitellozzo that of Borgo San Sepolcro. L 2 r.

[1] A profound student of the medical science of the Greeks. Died in 1525. (R.-M.)

[2] Albert the Little. Ravaisson-Mollien suggests the reference is to Leon Battista Alberti in contradistinction to Albertus Magnus who is mentioned in the following line.

[3] Giovanni Marliano, physician to Gion Galeazzo Sforza. Died 1483. Wrote 'De proportione motuum in velocitate'. (R.-M.)

[4] Albertus Magnus.

[5] Perhaps Raphaël Maffei de Volterra who wrote an attempt at an encyclopaedia. (R.-M.)

[6] Stoic philosopher. Works lost. Cicero studied under him. Richter has shown that Leonardo must have derived his knowledge from Strabo, who refers to Posidonius as having explained why the sun looked larger when rising or setting, than during the rest of its course.

Archimedes from the bishop of Padua. L 94 v.

Hermes the philosopher.[1] M cover v.

Of local movement.
Suisset, that is the Calculator.[2]
Tisber.
Angelo Fossombrone.[3]
Alberto.[4] M 8 r.

Pliny states that wool after having been boiled in vinegar is impenetrable.

Virgil says that the shield was white and without praises, because among the Athenians the true praises, which were such as were confirmed by the mouths of witnesses, formed the subject matter for the painters of shields; and these were made of stag bone bound together, set crosswise, and made smooth with . . . MS. 2037 Bib. Nat. 7 v.

Lucretius in the third book of his De Rerum Natura:—the hands, the nails, and the teeth were the weapons of ancient man. They used also as a standard a bunch of grass tied to a pole.

Tryphon of Alexandria, who passed his life at Apollonia a city of Albania. MS. 2037 Bib. Nat. 8 v.

Archimedes: 'De Ponderibus' [cited]. B.M. 16 r. and 17 r.

Euclid [cited]. B.M. 16 v.

'Ex ludis rerum mathematicarum' [cited as the title of a work by Leone Battista Alberti]. B.M. 66 r.

Roger Bacon done into print. B.M. 71 v.

Vitolone in San Marco. B.M. 79 r.

[1] This refers to the author of what are known as the Hermetic Books, which constituted a complete canon of ancient Egyptian religion, arts and science.

[2] Richard Suiseth, Cistercian, called the Calculator, was, according to M. Ravaisson-Mollien, a fourteenth-century English mathematician and astronomer who is stated by Leibnitz to have introduced mathematics into scholastic philosophy.

[3] Angelo Fossombrone was a fifteenth-century Italian mathematician.

[4] Alberto. The reference is presumably to Albertus Magnus.

Il Vespucci wishes to give me a book of geometry. B.M. 132 v.

On meeting with Lorenzo de' Medici I shall ask about the treatise on water of the bishop of Padua. B.M. 135 r.

Search in Florence for the Ramondina. B.M. 192 v.

Take the Ramondina.[1] Leic. 2 r.

The master Stefano Caponi, the physician, lives at the Piscina, he has Euclid: 'De Ponderibus'. Forster III 2 v.

Nonius Marcellus, Festus Pompeius, Marcus Varro.[2] Forster III 8 r.

The master Giuliano da Marliano has a fine herbal. He lives opposite to the Strami, the carpenters. Forster III 37 v.

[1] In the introduction to his edition of the Leicester Manuscript, Gerolamo Calvi suggests that these two lines refer to the search for and possession of a copy of one of the works of Ramon Lull, the Majorcan philosopher and mystic. This seems to offer a probable explanation of lines which otherwise form an enigma. An edition of Lull's *Ars generalis ultima* was printed in Venice in the year 1480, others of his works appeared in Rome and Barcelona. Leonardo may however have been in quest of one of his manuscripts. The so-called 'Lullian method', an attempt to supply a mechanical aid to the mind in the acquisition of knowledge by combinations formed by revolving circles, was dismissed in a couple of sentences by Francis Bacon: 'Any sciolist may make some show and ostentation of learning. Such was the art of Lullius'. The 'doctor illuminatus', as he was styled, is to-day a mere name in the history of philosophy, and such interest as exists in him centres in his work as poet and mystic. His latest biographer, Professor Peers, devotes a chapter each to his romances *Blanquerna* and *Felix* and a single page to his formidable *Ars Generalis*. But although the mechanical contrivances associated with the 'Lullian method' sufficed deservedly to discredit it, Lull as a thinker broke from the restraints of the schoolmen, and as the titles of certain chapters in his treatises serve to show, the workings of his curiosity concerning the laws of operation of natural forces offer many parallels to the writings of Leonardo. The field of his activities in science included geometry, astronomy, physics, chemistry, anthropology, the causes of wind and rain, the laws of navigation, and warfare. He was not unlike Roger Bacon in the extraordinary scope of his scientific interests; the two lines in which Leonardo expresses his desire to possess a work of Ramon Lull may be paralleled with the sentence, also in the Arundel Manuscript B.M. 71 v, 'Roger Bacon done into print'. Leonardo may very probably have owed the first awakening of his interest in the work of both to the fact of his association in study with Fra Luca Pacioli, who belonged to the Franciscan order, as did also Lull and Bacon, and who was therefore the more likely to have acquaintance with their works.

[2] Nonius Marcellus and Sextus Pompeius Festus were Roman Grammarians of about the fourth century A.D. Brunet (Manuel du Libraire) mentions an edition of the three authors printed at Parma in 1480.

The heirs of the master Giovanni Ghiringallo possess the works of Pelacano. Forster III 86 r.

Speculum of the master Giovanni Francesco.
Galen: De Utilità. Fogli B 2 r.

Have a translation made of Avicenna: On the Utilities.
The book on the science of machines precedes the book: On the Utilities. Quaderni I 13 v.

See: Concerning Ships by Messer Battista [Alberti], and Frontinus: Concerning Aqueducts.[1] Leic. 13 r.

Theophrastus: Concerning the Flow and Ebb. Concerning Whirlpools, and Concerning Water. Leic. 16 v.

[1] Alberti Leon. Batt. Incipit de re aedificatoria, Florentiæ 1485. Book V ch. 12 treats of ships and their parts.

Vitruvius, De Arch., et Frontinus, De Aquæductibus, Florentiæ 1513. The earliest edition of Sextus Julius Frontinus' chief work: De aquæductibus urbis Romæ commentarius. Its author had been appointed superintendent of the aqueducts at Rome.

L

Miscellaneous

'The duke lost his State, his personal possessions and his liberty, and none of his enterprises have been completed.'

Pandite iam portas miseri et subducite pontes
  Nam Federigus adest quem Gebelina sequor.
Dic quid fulmineis euertis menia bombis?
  Stabunt pro muris pectora colligenum.
Diruta cesserunt nostris tua menia bombis:
  Diruta sic cedent pectora pectoribus.[1]

(Throw open now the gates, ye wretched ones, and lift up the drawbridges, for Federigo approaches whom I the Ghibellina follow! Say why thou overturnest thy ramparts with murderous bombs? The hearts of the host will stand in defence of the walls. Your ramparts overthrown have yielded to our bombs, so let your hearts overthrown yield to our hearts.) C.A. 28 r. b

The action of cutting the nostrils of horses is a practice worthy of derision. And these fools observe this custom, almost as though they believed nature to be lacking in necessary things, in regard to which men have to be her correctors.

Nature has made the two holes in the nose, each of which is half the width of the pipe from the lungs by which the hard breathing goes out; and if these holes were not there the mouth would suffice for this abundance of breathing.

And if you should ask me why nature has made the nostril thus in animals, when the breathing through the mouth is sufficient, my reply

[1] The lines refer to the siege of Colle, taken by storm from the Florentines in November 1479 by the Duke of Calabria and Federigo Duke of Urbino. The Ghibellina is the name of a piece of artillery (see Calvi *MSS. di L.*, p. 45).

would be that the nostrils are made for the purpose of their being used when the mouth is occupied with masticating its food. C.A. 76 r. a

Se voi star sano, osserva questa norma:
non mangiar sanza voglia, e cena leve;
mastica bene, e quel che in te riceve,
sia ben cotto e di semplice forma.
Chi medicina piglia, mal s'informa;
guarti dall'ira e fuggi l'aria grieve;
su diritto sta, quando da mensa leve;
di mezzogiorno fa che tu non dorma.
El vin sia temprato, poco e spesso,
non for di pasto nè a stomaco voto;
non aspectar, nè indugiare il cesso;
se fai esercizio, sia di picciol moto.
Col ventre resupino e col capo depresso
non star, e sta coperto ben di notte;
el capo ti posa e tien la mente lieta,
fuggi lussuria, e attienti alla dieta.

(If you would keep healthy, follow this regimen: do not eat unless you feel inclined, and sup lightly; chew well, and let what you take be well cooked and simple. He who takes medicine does himself harm; do not give way to anger and avoid close air; hold yourself upright when you rise from table and do not let yourself sleep at midday. Be temperate with wine, take a little frequently, but not at other than the proper meal-times, nor on an empty stomach; neither protract nor delay the [visit to] the privy. When you take exercise let it be moderate. Do not remain with the belly recumbent and the head lowered, and see that you are well covered at night. Rest your head and keep your mind cheerful; shun wantonness, and pay attention to diet.)

C.A. 78 v. b

A nude by Perugino. C.A. 97 r. a

TO MELT PEARLS

If you wish to make a paste out of small pearls take the juice of some lemons and put them to soak in it, and in a night they will be dissolved. And when it has all settled throw away the lemon juice and put fresh, and do this two or three times, so that the paste may be very fine. Then wash the said paste with clear water a sufficient number of times for it to lose all trace of the lemon juice. After doing this let the paste dry so that it turns to powder. Then take white of egg, beat it well and leave it to settle, and then moisten the said powder with this so that it becomes a paste again.

And from this you can make pearls as large as you wish, and leave them to dry. Then place them in a small turning lathe and polish them, if you wish with a dog's tooth, or if you prefer with a polishing stick of crystal or chalcedony.

And polish it until it has the same lustre that it had before. And I believe that if you dissolve mother-of-pearl you get the same result as with the pearls. C.A. 109 v. b

Book of Pandolfino—knives—pen for ruling—to dye the cloak—Library of St. Mark's—Library of Santo Spirito—Lattanzio Tedaldi—Antonio Covoni—book of Messer Paolo, the hospital superintendent—boots shoes and hose—varnish—boy to serve as a model—grammar of Lorenzo de' Medici—Giovanni del Sodo—Sansovino—ruler—very sharp knife—spectacles—*rotti fisici*—repair the labyrinth[?] (*l'abernucco*)—book of Tommaso—the small chain of Michelangelo—learn how to multiply roots from Messer Luca—my map of the world which Giovanni Benci has—slippers—clothes from the excise man—red Spanish leather—map of the world of Giovanni Benci—a print of the country round Milan—marketing books—bow and cord—Tanaglino—Moncatto. C.A. 120 r. d

Prophecy of Lionardo da Vinci.[1] C.A. 194 v. a

To bring a crucifix into a room. C.A. 207 r. a

The Venetians have boasted of their power to spend thirty-six millions of gold in ten years in the war with the Empire, the Church, the Kings of Spain and of France, at three hundred thousand ducats a month. C.A. 218 r. a

[1] This line is written vertically on a page of pure mathematics.

Messer Battista dall' Aquilo, the Pope's private chamberlain, has my book in his hands. C.A. 287 r. a

TO MAKE SCENT

Take fresh rose-water and moisten the hands, then take the flower of lavender and rub it between the hands, and it will be good.

C.A. 295 r. a

If on delight your mind should feed.
(*Se di diletto la tua mente pasce.*) C.A. 320 r. b

OF A BLOW THE CAUSE OF FIRE

If you beat a thick bar of iron between the anvil and the hammer with frequent blows upon the same spot, you will be able to light a match at the spot which has been struck. C.A. 351 v. b

I will say one word or two or ten or more as pleases me, and I wish that in that time more than a thousand persons say the same in that same time, so that they may immediately say the same as me. And they will not see me nor perceive what I say.

These will be the hours enumerated by you, for when you say one, all those who enumerate the hours as you do will say the same number as you at the same time. C.A. 384 r. a

[*With sketch of flock of birds rising in flight*]

This stratagem was employed by the Gauls against the Romans, and so great a mortality ensued that all Rome was dressed in mourning.

Tr. 18 a

Sea water filtered by mud or clay deposits in it all its saltness. Woollen stuffs spread over the sides of ships absorb the fresh water. If it be distilled by means of a retort sea water becomes of first excellence, and by making use of a cooking stove in his kitchen any one can, with the same wood as he cooks with, distil a greater quantity of water if the retort is a large one. Tr. 44 a

One may make of wood thin grained boards, which will seem like camlets and watered silks and with various fixed marks. F 2 r.

When a horse is moving in water it creates less foam when it is more submerged and more foam when less submerged. This proceeds from the fact that the legs when less submerged are less impeded, and consequently move more rapidly and drive the water more with their great hoofs than with their knees and thighs. G 11 r.

Remember the solderings which were used to solder the ball of Santa Maria del Fiore. G 84 v.

To lock with a key a sluice at Vigevano. H 1 r.

A nun lives at the Dove at Cremona who is a good maker of straw plaits, and a friar of San Francesco. H 62 [14] v.

[*Memoranda*]

Needle. Niccolò.
Thread.
Ferrando.
Jacopo Andrea.
Canvas.
Stone.
Colours.
Brushes.
Palette.
Sponge.
Panel of the Duke. H 94 [46] r.

[*Sun dial*]

To measure the stages of the time by the sun. H 97 [45 r.] v.

[*Viticulture*]

The peasant seeing the usefulness of the products of the vine gives it many props in order to keep up its branches; and after the fruit has been gathered he takes away the poles and allows them to fall; making a bonfire of the supports. H 112 [31 r.] v.

[*List of household utensils*]

New tin ware.
Six small bowls.
Six bowls.

Six large plates.
Two medium-sized plates.
Two small plates.
Old tin ware.
Three small bowls.
Four bowls.
Three square tiles.
Two small bowls.
One large bowl.
One plate.
Four candlesticks.
One small candlestick.
Three pairs of sheets of four widths each.
Three small sheets.
Two table cloths and a half.
Sixteen coarse table cloths.
Eight shirts.
Nine woollen cloths.
Two towels.
One basin. H 137 [6 r.] v.

[*Sensibility of the hair of the ox*]

The hair of the ox placed in stagnant water in summer acquires sensation and life and movement of itself, and also the power of fear and flight and perception of pain. And the proof is that if it is pressed it twists and releases itself. Place it again in the water, as before it takes to flight and removes itself from the danger. K 81 [1] r.

SCENTLESS OIL

To take away the smell from oil:

Take some crude oil and put ten pints of it in a vessel. Make a mark on the vessel according to the height of the oil, and then proceed to add a pint of vinegar, and boil until the oil has gone down as low as the mark that was made. By this means you will be sure that the oil has come back to its first amount and that all the vinegar has evaporated, and has carried all the bad smell away with it.

I believe that it is possible to do the same with nut oil, and with every other oil which has a bad smell. K 112 [32] v.

If you have some strong glue, half tepid and half cold, and only slightly liquid, and press paste of vermicelli on it, congealed and solidified, and of any colour you like, this will make very beautiful twists, and the parts of them will be exactly like thin narrow ribbons. K 118 [38] r.

Decipimur votis et tempore fallimur: et mos
Deridet curas; anxia vita nihil.

(We are deceived by our vows and deluded by time, and habit derides our cares; the anxious life is nothing.) L cover r.

[*Events in Milan in* 1500]

Paolo di Vannocco at Siena.

Domenico Chiavaio.

The small hall above for the apostles.

Buildings by Bramante.

The governor of the castle made prisoner.

Visconti dragged away and then his son slain.

Gian della Rosa robbed of his money.

Borgonzo began and was unwilling and so fortune deserted him.

The duke lost his State, his personal possessions and his liberty, and none of his enterprises have been completed.[1] L cover v.

[1] The note 'buildings by Bramante', in view of the fact that those which follow relate to untoward events consequent upon the imprisonment of Ludovic Sforza, refers possibly to the fact of various works designed by Bramante being left uncompleted, e.g. according to Amoretti one side only of the Canonica di S. Ambrogio was built, and the columns for the rest lay there for upwards of a century. According to the same authority the reference to the governor of the castle was in all probability to the French governor, who on the return of the French was thrown into prison for having surrendered to Ludovic when his troops reoccupied the city; he cites the names of two Visconti from Arluno's chronicle who were carried off as captives into France for having taken the side of the Duke; Gian della Rosa he identifies with Giovanni da Rosate, professor at Pavia, the Duke's physician and astrologer; and Borgonzo with Brugonzio Botta, the administrator of the ducal revenue, whose house was pillaged by the French partisans on his flight.

The notes end with Leonardo's laconic epitaph upon the fallen fortunes of Ludovic Sforza, who at the time they were written was a prisoner at Loches in Touraine, where he remained until his death.

[*Various notes*]

Piece of tapestry.
Pair of compasses.
Book of Tommaso.
Book of Giovanni Benci.
Box at the custom house.
To cut out the dress.
Belt of the sword.
To resole the shoes.
A light hat.
Thatch from the ruined houses.
The debt for the cloth.
Bag for swimming.
Book of white paper for drawing.
Charcoal. L I V.

[*With diagram*]

O se d'un mezo circol far si pote
triangol sì ch'un recto non avessi
e che gli altri due un retto non faciessi.[1] B.M. 33 V.

Sulphur and pitch; sulphur and lead; sulphur and gum mastic; sulphur and varnish, and mixed with the husks of pine-kernels, sawdust of the spindle-tree, and isinglass, and nuts of cherries and blackthorn, and shells of snails, or husks of beans soaked and then dried in the sun so that they shrivel, and seed of myrtle with the said glue.

B.M. 47 V.

Market book—waters of the Clonica—waters of the Tanaglino—Moncatto—the caps—the mirror of Rosso, to watch him make it—(⅓ *di che numero* ⅚)—the Metaura of Aristotle—boxes of Lorenzo di Pierfrancesco—Maestro Piero dal Borgo—to have my book bound—show the book to Serigatto and get him to give the rule of the clock . . . (*dell' orilogio anello*)—nutmeg—gum—square—Giovanni Battista at the piazza de' Mozzi—Giovanni Benci, my book and jaspers—brass for the spectacles. B.M. 190 V.

Box—instrument for observing levels—book of Pandolfino—small

[1] The two first lines are taken from Dante's *Paradiso* XIII 101-102.

knives—pen for ruling—to dye the cloak—libraries—Lattanzio Tedaldi—book of Messer Paolo the hospital superintendent—boots hose and shoes—varnish—boy for the models—grammar of Lorenzo de' Medici—Giovanni del Sodo (*per rotti fisici*)—Sansovino—Piero di Cosimo—Filippo and Lorenzo—a ruler—spectacles—to repair the labyrinth—book of Tommaso—chain of Michelangelo—multiplications of roots—of cord and bow—map of the world of the Benci—slippers—clothes from the excise man—Spanish leather—cage—to fatten the bird—(*Renieri pella pietra stella*)—the cup of Alfieri—the Metaura—go to the house of the Pazzi—small box—small gimlet—I have procured two long nails from the Antellesi—(*La valuta del botro*)—the value of the taffeta for the wings. B.M. 191 r.

Where is Valentino?
Boots
Boxes at the custom house
Monk of the Carmine
Squares
Piero Martelli
Salvi Borgherini
Send back the sacks
Support for the spectacles
The nude of Sangallo
The cloak
Porphyry
Knots
Square
Pandolfino. B.M. 202 v.

Friday morning one florin to Salai for expenses: he had three soldi left. For bread, wine, eggs, mushrooms, fruit, bran, for the barber and for shoes. B.M. 272 v.

Had anyone discovered the range of the power of the cannon in all its varieties and imparted his secret to the Romans, with what speed would they have conquered every country and subdued every army? And what reward would have been deemed sufficient for such a service? Archimedes, although he had wrought great mischief to the Romans at the storming of Syracuse, did not fail to be offered very great rewards by these same Romans. And at the sack of Syracuse diligent search was made for Archimedes, and when he was found to be dead there was a greater lament made in the senate and among the Roman people than if they had lost all their army, and they did not fail to honour him with obsequies and statue, their leader being Marcus Marcellus.

And after the second destruction of Syracuse the tomb of this same Archimedes was rediscovered by Cato among the ruins of a temple, and so Cato caused the temple and tomb to be restored most elaborately; and as to this Cato is recorded to have said that he did not glory in any of his actions so much as in having paid this honour to Archimedes. B.M. 279 v.

Make a cupful of paste and millet rendered to a jelly, or flowers of elder or others like these. Forster II 2 r.

Arrigo ought to have eleven gold ducats.
Arrigo ought to have four gold ducats by the middle of August.
Forster II 24 v.

See the letter to Santa Maria—secret. Forster II 25 r.

Have ears of corn of great size sent from Florence. Forster II 38 v.

Giuliano da Maria the physician has a steward without hands.
Forster II 43 v.

Paul was snatched up to heaven. Forster II 45 v.

Giuliano Trombetta.
Antonio de Ferrara.
Oil from clay. Forster II 52 v.

Count Francesco Torello. Forster II 57 r.

Messer Gian Domenico Mezzabarba and Messer Giovanni Francesco Mezzabarba, by the side of Messer Piero da Galera under the covered way, owe for the water. Forster II 57 v.

Parsley	ten parts
Mint	one part

Wild thyme	one part
Burnt bread	ten parts
Vinegar, pepper and salt	a little.

Two dark purple dusters for Salai. Forster II 60 v.

Beans, white maize, red maize, panic-grass, millet, kidney beans, broad beans, peas. Forster II 65 r.

Tuesday you will buy the wine for the morning.
Friday on the fourth day of September the like.

[*Sketch*]
Tell me for what reason a muddy ball struck against a wall leaves an impression if it has been well blown up? Forster II 159 r.

HOW TO MAKE AMBER ROUGHENED

Take white of egg and put it into a sausage skin and boil it; after it has grown hard paint over the spots, then cover it over with more white of egg and put it back into a larger skin. Forster III 33 v.

Add pyrites to aqua fortis and if it turns green know that it contains copper. Precipitate this with saltpetre and soft soap. Forster III 37 v.

On the first day of February twelve hundred lire. Forster III 45 v.

AQUA FORTIS

One part Roman vitriol, one saltpetre, one cinnabar, one verdigris.

TO DISSOLVE COPPER

Dissolve the copper with these waters and then evaporate it so that it becomes like paste or mustard, and daub it over your figure and polish it well with a brush and dry it; then cover it with earth out of doors and make a great fire in such a way that the copper between the two layers of earth becomes united, or mix this copper with quicksilver. Forster III 59 v.

If lime and orpiment make a depilatory, lye or distillation make it, and it will dissolve hairs and horn and bristles and nail.

Forster III 74 r.

Among Europeans long nails are looked upon as shameful, and among the Indians they are held in great veneration, and they anoint them with fragrant scents and adorn them with various patterns; and they say that they are the mark of people of gentle birth, and that short nails are a sign of working-class people and mechanics in different trades.

Fogli B 3 r.

That power shows itself to be greater which is impressed upon a weaker, that is, a lesser resistance.

This conclusion is universal and it avails for the flow and ebb to prove that the sun or moon impresses itself so much the more upon the object, that is upon the waters, as they are of less depth; and therefore the shallow waters of the marshes must receive the cause of the ebb and flow with greater efficacy than do the mighty depths of the ocean.

MEMORANDUM [1]

To go to make arrangements for my garden.
Giordano 'De Ponderibus'.
The reconciler of the flow and ebb of the sea.
To have two boxes made to go on a pack saddle.

[1] The fact may perhaps not be without significance that this memorandum, which the order of arrangement of passages from the various manuscripts has caused to come at the end of this book, contains two sentences in which, alongside the record of matters of daily import, there is a deeper note discernible and one which, as it seems, sounds in unison across the centuries. In the words 'to go to make arrangements for my garden' (*andare in provitione per il mio giardino*) there is a curious similarity to the words as almost to the mood of thought that finds expression in the apophthegm in *Candide* 'il faut cultiver notre jardin'. Each perhaps may contain the formula of renunciation.

So also in like manner the third line of the memorandum 'the reconciler of the flow and ebb of the sea' seems to me to link itself unforgettably in the memory with two lines of Keats:—

'The moving waters at their priestlike task
Of pure ablution round earth's human shores'.

The two present essentially the same image. If you surrender to them they have the same beauty of suggestion.

With Leonardo, however, the mood changed. Any thought of the movement of water might give rein to practical considerations as to possibilities of harnessing its power for

See Boltraffio's turning lathe and have a stone taken away.

Leave the book for Messer Andrea Tedesco.

Use an arrow as a balance and weigh the substance when heated and then weigh it again cold.

The mirror of Messer Luigi.

Oil petroleum.

[*Figure a b*] Flow and ebb of the waters, proved at the mill of Vanrio [Vaprio?]

Cap. Quaderni II 22 v.

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public utility. The last line of the memorandum is '*a b* flow and ebb of the waters, proved at the mill of Vanrio', the letters having reference to a small drawing of hydraulic apparatus immediately at the side of the page. If Vanrio may be interpreted as Vaprio, the reference would be to the waters of the Adda, to the mill at Vaprio on the Adda, Vaprio being the country home of the Melzi family, a member of which—Francesco Melzi—became like an adopted son to Leonardo. It was to Vaprio that Leonardo, during the later years of his life in Milan, frequently went in order to pursue research in quiet. Were this memorandum a record of impulses, the word *beretta* (cap), which concludes it, coming immediately after the mention of the mill might almost suggest that he was thinking of going there.

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II General

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